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THE TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

EDITED BY

ROBERT P. BIGELOW, Ph. D.

THE TECHNOLOGY QUARTERLY is an illustrated magazine published by the MASSACHUSETTS INSTITUTE OF TECHNOLOGY. It is devoted to original articles upon various subjects in **Architecture, Civil Engineering, Mechanical Engineering, Electrical Engineering, Physics, Chemistry, Biology, Bacteriology, Mining** and **Metallurgy,** or, in general, the **Sciences** and their applications to the **Useful Arts.** Attention is called to two especially notable features of the QUARTERLY, viz.: *The Results of Tests made in the Engineering Laboratories* and *The Review of American Chemical Research.*

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AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

VOL. XIV. MARCH, 1901. No. 1.

PROCEEDINGS OF THE SOCIETY OF ARTS.

THIRTY-NINTH YEAR, 1900–1901.

BOSTON, October 11, 1900.

THE 542d regular meeting of the SOCIETY OF ARTS was held on this day at 8 P.M., in Room 22, Walker Building, Mr. George W. Blodgett presiding. Two hundred and seventy-five persons were present. The records of the Annual Meeting for the year 1899–1900 were read and approved. Messrs. C. B. Beasom and Franklin H. Davis, graduates of the Institute, were elected to Associate Membership. There being no further business, the Chairman introduced Mr. Louis Derr, Instructor in Physics at the Institute, who addressed the Society on "Color Photography"

The speaker referred to the well-known differences in the colors produced by the mixture of pigments and by the mixture of colored light. In the latter case the three primary sensations, or colors, are red, green, and violet, and by their proper combination the sensation of white or any known color may be produced. This forms the underlying principle of the Ives process for the reproduction of natural color effects. A lantern is provided with three sets of lenses, which transmit light respectively through three colored glasses, red, green, and blue-violet. By a suitable mechanical device the three col-

ored images overlap on the screen, and give a white image. Three negatives of an object are made through red, green, and blue-violet glasses respectively, and their corresponding positives formed. The positive obtained by the use of red glass is placed in front of the lens system which gives red light, and correspondingly for the other two positions. Reflection will show that on the screen the original object should appear in the natural colors. Many beautiful slides were shown. The objections to the process are the mechanical difficulties in securing the correct color toning, and the cost and labor of obtaining satisfactory positives. The Ives Kromoskope was also explained.

The second process described was one suggested by Professor Joly, of Dublin. It depends upon the theory of color mixtures, and the fact that the eye is unable to differentiate objects whose visual angle is less than 1 minute of arc. A plate of glass is ruled in succession with red, green, and blue-violet lines to the number of 80 each to the inch. An object is photographed through such a plate, the positive formed, and the latter is viewed through the original test plate, using white light as the source of illumination. The Joly process is essentially the Ives process reduced to the formation of the three-colored positives on one plate.

McDonough, of Chicago, has succeeded in ruling plates with 100 sets of lines to the inch, thus securing a more perfect color reproduction of the small details of an object. Certainly the Joly-McDonough process gives most satisfactory and true reproduction in color, if the slides which were shown are to serve as a criterion.

The last view which was shown, was one taken by the Lippmann process. This process is most interesting, since it is based on the interference of light, and gives a "true color photograph." By none of the processes is direct color printing possible. They merely offer a means of securing transparent positives in color.

The thanks of the Society were extended to Mr. Derr for his most entertaining and instructive lecture.

BOSTON, October 25, 1900.

The 543d regular meeting of the SOCIETY OF ARTS was held on this day at 8 P.M., in the Rogers Building, Mr. Desmond FitzGerald presiding. Seventy-two persons were present. The records of the

previous meeting were read and approved. The following were elected to Associate Membership: Dr. William H. Walker, Chemist; Mr. E. M. Fisher, of the Associated Press; Mr. H. P. Quick, with the Boston Elevated Railroad.

At the conclusion of the business portion of the meeting, Professor Wallace C. Sabine, of Harvard University, was introduced, and addressed the Society on "Some Experiments in Architectural Acoustics," limiting his remarks to those experiments which may be classified under the head of "Reverberation." A synopsis of the lecture will not be given as Professor Sabine has kindly presented his monograph on Reverberation to the Society.

As a piece of original research of unusual merit and value, the investigations on Architectural Acoustics, carried on by Professor Sabine during the last five years, are deserving of the highest commendation. For those present it was most interesting and instructive to learn of the earlier experiments, and to see how they led to more extensive and far-reaching investigations, ultimately resulting in a satisfactory and complete solution of the problem.

The thanks of the Society were most heartily extended to Professor Sabine for his valuable address.

BOSTON, November 8, 1900.

The 544th regular meeting of the SOCIETY OF ARTS was held on this day at the usual hour in the Walker Building. One hundred and thirty-five persons were present.

The following gentlemen were elected to Associate Membership: Mr. Olof Ohlson, Assistant Superintendent of Waltham Watch Factory; Mr. S. W. Wilder, Jr., Manager of the Merrimac Chemical Company; Mr. Edgar M. Hawkins, Mechanical Engineer, and Mr. J. E. Woodwell, Inspector of Electric Lights, Treasury Department, Washington.

There being no further business, the Society was privileged to listen to a most interesting lecture by Dr. Henry S. Pritchett, President of the Institute of Technology and of the Society, on "America's Contribution to our Knowledge of the Size and Figure of the Earth." The lecture had particular reference to the magnificent work which has been

done by the United States Coast and Geodetic Survey on the measurement of an arc of the 39th parallel, extending from Cape May Lighthouse to Punta Arenas in California, a distance of 4,224 kilometers. These measurements were begun in 1871, at the suggestion of Professor Benjamin Peirce, and completed in 1898, during the administration of Dr. Pritchett as Superintendent of the Coast and Geodetic Survey.

The main discussion of the figure of the earth rests upon the measurements of three arcs of meridian; one in Peru, one in Finland, and a third near the Cape of Good Hope. The Peruvian arc, determined in 1735, has remained as a standard in all geodetic work. Owing to the demand for its accurate remeasurement, the French Government has arranged to send an expedition in the Spring, which will remeasure the old arc and extend its length.

The 39th parallel was chosen by the United States Government as forming the longest line running east and west in the United States. The methods used in the base-line measurements,[1] as well as the procedure of triangulation were carefully described. Reference was also made to the improvements which had been made in instruments for measuring latitude, longitude, and altitude with the requirements of the survey. It should not be forgotten that the measurements were made over mountain ranges, in most inaccessible regions, at great risk to life, and testify to the courage and perseverance of the men engaged in the undertaking. Their reward lies in the knowledge that this arc is the longest ever measured with accuracy on the earth's surface, and gives to the earth the same figure as that determined from smaller arcs measured in Europe and Asia; agreeing with the spheroid as calculated by Captain Clark in 1880.

Besides the determination of the earth's figure, this arc of the 39th parallel is most valuable as a connecting link between the surveys of the Atlantic and Pacific Coasts, and, since it passes through sixteen states, serves as a sort of primary reference survey for all these states.

The thanks of the Society were tendered to Dr. Pritchett by Professor Swain on behalf of the Society.

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[1] An article on An Improvement in the Base-Line Measuring Apparatus, by Professor A. E. Burton, with a description of a successful test of it by the United States Coast and Geodetic Survey, is in the hands of the Editor and will appear in the next issue of this journal.

BOSTON, November 22, 1900.

The 545th regular meeting of the SOCIETY OF ARTS was held on this day in the Rogers Building, at 8 P.M., Mr. George W. Blodgett presiding. Seventy-five persons were present. Messrs. Howard D. Coburn and Arthur G. Woodman were elected to Associate Membership.

At the conclusion of the business part of the meeting, the speaker of the evening, Professor W. W. Crosby, Principal of the Lowell Textile School, was introduced and spoke on "Applied Science in the Textile World." After a most interesting statement of the need and advantage of science as applied to industries of all kinds, the speaker referred to the primitive methods used in the earlier textile industries, and compared them with the modern methods. The wonderfully ingenious machines for spinning and weaving, among them the card, mule, ordinary and Jacquard looms were explained.

A short reference was made to the aim of the Lowell Textile School, and many slides were shown illustrative of the splendid equipment which the school possesses.

The thanks of the Society were tendered the speaker, after which the meeting adjourned.

BOSTON, December 13, 1900.

The 546th regular meeting of the SOCIETY OF ARTS was held on this day at the Institute, Rogers Building, at 8 P.M., Mr. James P. Munroe presiding. One hundred and fifteen persons were present. After the reading and adoption of the report of the previous meeting, Mr. Guy Lowell, Architect, addressed the Society on "Landscape Architecture in this Country."

The history of landscape architecture dates back many years before the Christian era; indeed, descriptions of Egyptian gardens as far back as 1500 B.C. are mentioned in hieroglyphics. The art of gardening continued during the Roman Empire, but gradually died out. During the Renaissance, an awakening took place which has grown in its influence, especially since the beginning of the Seventeenth Century, when the Italian gardens became so famous. These gardens were laid out with geometrical regularity, adorned with statuary, native plants and trees. The terraces were their chief characteristics.

The French gardens were similar to the Italian gardens in the formality of lines and geometrical curves. During the reign of Louis XIV, some of the most famous gardens of France were constructed. These were usually free from terraces, but remarkable for long vistas, and profusion of arches, fountains, and grottoes.

With the spread of gardens through Europe, the "Formal" style of the ancients gradually yielded to conditions of climate and vegetation. In England, Kent abandoned the steep terraces and straight lines, substituting flowing lines, slopes, pleasing curves, irregularity in the arrangement of trees and shrubs.

The speaker emphasized that specific rules cannot be laid down in landscape architecture; the climate, character of land, and architecture must dominate the style. In this country the "Formal" gardens will doubtless be supplanted by gardens in which the wonderful richness and beauty of nature will be seen in all its glory. Untrimmed trees and flowering shrubs will be the principal features.

The thanks of the Society were extended to the speaker.

GEORGE V. WENDELL, *Secretary.*

THE ECLIPSE EXPEDITION OF THE CREIGHTON UNIVERSITY TO WASHINGTON, GEORGIA.

By WILLIAM F. RIGGE, S.J.

CREIGHTON UNIVERSITY has contributed its share towards the scientific observation of the total solar eclipse of May 28, 1900, so far as its means and circumstances permitted. As this great event occurred toward the end of the college year when its professors were unusually occupied with class duties and examinations, the Professor of Astronomy, the writer of the present account, was the only one who could be devoted to the work. Having invited the Professors of Astronomy of sister colleges to participate in the noble cause, Rev. Charles Charroppin, S.J., and Professor Aloysius Frumveller, S.J., of St. Louis University, St. Louis, Missouri, and Professor William P. Quinlan, S.J., of St. Xavier College, Cincinnati, Ohio, recognizing Creighton's initiative and its judicious selection of the site, freely offered a hearty coöperation. Washington, Georgia, was chosen as the place of observation, and the elegant little pastoral cottage attached to the St. Joseph's Academy and Orphanage, the occupant of which had just died in a hospital in Baltimore, was placed at our entire disposal, and every facility was offered for our work.

The observatory of Creighton University, at Omaha, Nebraska, while surpassed but by few students' observatories in the country, is not equipped with special eclipse instruments. Its 5-inch Steward equatorial, its 3-inch Fauth transit and meridian circle reading to tenths of a second, with its chronograph and its Howard mean time and Fauth sidereal clocks, are not portable, and as time and means were limited, their transportation and remounting were out of the question. The writer therefore had to content himself with an excellent chronometer and a 3-inch telescope with a tripod and an ordinary altazimuth mounting. But with this comparatively meager instrumental outfit, he was determined to do his best. To do work of real service to astronomical science, he further restricted himself exclusively to the observation of the four contacts. Then, as a professor of astronomy, he devoted the

rest of his energy to the visual observation of the corona and other phenomena of the eclipse. The other members of the party had mounted six cameras upon one support, and were intent upon the photographic reproduction of the corona.

Station.

Upon the grounds of the St. Joseph's Orphanage and Academy at the western end of Washington, Georgia, there are four main buildings connected by a private walk. Of these the Orphanage is at the northern end, the little cottage which served as our headquarters is next, then comes the Catholic church, and lastly the Academy at the southern end. While the rest of my party had erected their cameras in front, or east of the cottage, I took up my station on the walk halfway between the church and the residence, where, as I had planned, I was absolutely alone and entirely unbiased by the doings of others. Afterwards, when I realized that my observations were better than I had anticipated, I engaged Mr. Wiley G. Tatom, the Surveyor of Wilkes County, to connect my station with that of the Massachusetts Institute of Technology at the southern end of the town. Under date of June 22, 1900, he sent me the following field notes:

	Bearings.			Distances. Chains.
1	S.	66°	E.	5.00
2	S.	86½°	E.	43.60
3	S.	5°	W.	28.00
4	S.	60°	E.	7.30

The departures and differences of latitude are as follows, the distances being expressed in feet:

	Bearings.	Distances.	N.	S.	E.	W.
1	S. 66° E.	330	....	134	302	....
2	S. 86½° E.	2,878	....	176	2,872	....
3	S. 5° W.	1,848	....	1,841	....	161
4	S. 60° E.	482	....	241	417	
				2,392	3,591	161
					161	
				2.392	3,430	

FIG. 1.—METHOD OF OBSERVATION.

According to the Smithsonian Geographical Tables, 1894, these distances are equivalent to 23.7″ and 2.71*s.* respectively. Hence

	Latitude.			Longitude.		
Massachusetts Institute of Technology	33°	43′	49″	5*h.*	30*m.*	56.2*s.*
Reduction	+		23.″7	+		2 7*s.*
Creighton University	33°	44′	13″	5*h.*	30*m.*	58 9*s.*

The station of the Massachusetts Institute of Technology was therefore 4,180 feet S. 55° 7′ E. of that of the Creighton University.

The Method of Observation.

The internal contacts were observed with the naked eye. The external contacts were observed by projecting the sun's image upon a white screen secured by two light wooden rods beyond the eye-piece of the 3-inch telescope (see Figure 1). I prefer this way of observing the sun to the more usual direct-vision method by means of a sunshade or helioscope, because the projection method does away with the heat and glare of the sun, admits of the use of both eyes and of any desirable magnifying power, is equal, if not superior in accuracy of observation, and especially because it enables the observer to mark the point of first contact upon the screen and thus obtain the advantages of a position micrometer from a telescope of the most ordinary construction and mounting.

The Chronometer.

The chronometer was the box chronometer without its box, H. H. Heinrich, No. 502, beating half seconds. It kept central, or 90th meridian, time. The correction and rate were obtained from the 75th meridian noon signals at the railroad depot, which was at about a five minutes' walk from our cottage. As the signals were less than a tenth of a second in error, being 0.04*s.* late on May 26, and 0.02*s.* fast on May 28, their correction has been neglected. The chronometer corrections were as follows:

May 26, 1900	+	1*m.*	1.2*s.*
May 28, 1900	+	0	47.0

Hence the rate was 7.1*s.* a day gaining, or 0.3*s.* in one hour.

THE TIMES OF THE CONTACTS.

	I.	II.	III.	IV.
	h. *m.* *s.*	*h.* *m.* *s.*	*h.* *m.* *s.*	*h.* *m.* *s.*
Chronometer face	6 32 30	7 40 2	7 41 28	8 58 31
Correction at 11*h.* . . .	+ 47.0	+ 47.0	+ 47.0	+ 47.0
Rate to observed time . .	+ 1 3	+ 1.0	+ 1.0	+ 0.6
Central times	6 33 18 3	7 40 50 0	7 42 16.0	8 59 18 6

Comparison of Computed and Observed Times.

In preparation for the eclipse, the erroneous values of 33° 40′ 46″ for the latitude, and 5*h.* 30*m.* 49.5*s*, for the longitude, as measured from the government eclipse map, had been used. As soon as the true coordinates of my position became known to me, I recomputed the times of the phases and obtained the following results:

Central Time.	I.	II.	III.	IV.
	h. *m.* *s.*	*h.* *m.* *s.*	*h.* *m.* *s.*	*h.* *m.* *s.*
Computed	6 33 17 0	7 40 57.1	7 42 23 0	8 59 29 8
Observed	6 33 18.3	7 40 50.0	7 42 16.0	8 59 18.6
Computed — Observed . .	— 1.3	+ 7.1	+ 7.0	+ 11.2

Central Time.	Mid Totality.	Duration of Totality.	Duration of Whole Eclipse.
	h. *m.* *s.*	*m.* *s.*	*h.* *m.* *s.*
Computed	7 41 40.0	1 25.9	2 26 12.8
Observed	7 41 33.0	1 25.0	2 26 0.3
Computed — Observed . . .	+ 7.0	— 0.1	+ 12 5

Comparison of Times as Observed by Creighton University and Massachusetts Institute of Technology Parties.

A very interesting and useful part of the observations of the contacts in an eclipse is the comparison of the times as observed by different parties. It was only on November 23, 1900, that a reprint

from the *Technology Quarterly*, Vol. XIII, No. 3, September, 1900, containing the account of the "Eclipse Expedition of the Massachusetts Institute of Technology to Washington, Georgia," came into my hands. It had been kindly sent to me by Mr. G. L. Hosmer. As soon as I saw the observed times of the phases, I set to work at once to compare them with my own. For this purpose a reduction had to be computed which would make the observations at both stations comparable with one another. As this computation involved a considerable amount of labor, I thought a somewhat extended explanation of my method would be acceptable to the readers of this journal. I shall try to be brief without being obscure.

Reduction of the Times of the Exterior Contacts.

For the external contacts sufficient accuracy is secured by measuring the direction of the tangent to the moon's penumbra as given for every two-and-a-half minutes for the beginning, and every five minutes for the end of the eclipse, on the government map in the supplement to the *American Ephemeris*, 1900, and then supposing the direction of the penumbral motion to be at right angles to this tangent. The velocity was obtained by measuring the number of miles run in a minute, or the number of feet run in a second, on either side of Washington on the map. This gave the following results:

Penumbral front moved 3,942 feet a second from S. 14° W.
Penumbral rear moved 2,587 feet a second from S. 53° W.

Figure 2 represents the comparative location of the two observing stations and the direction of motion of the moon's penumbra at the external contacts. It will be seen that the first contact occurred 0.38*s*. sooner, and the fourth contact 0.50*s*. later, at the Massachusetts Institute of Technology station than at the Creighton University station. Hence the correction to the observed M. I. T. (Massachusetts Institute of Technology) times is + 0.4*s*. and — 0.5*s*. respectively, to reduce them to the C. U. (Creighton University) station.

Reduction of the Times of the Interior Contacts.

There are, in general, two kinds of solutions, according as the Fundamental Plane or the Washington Horizontal Plane is taken as the basis of computation.

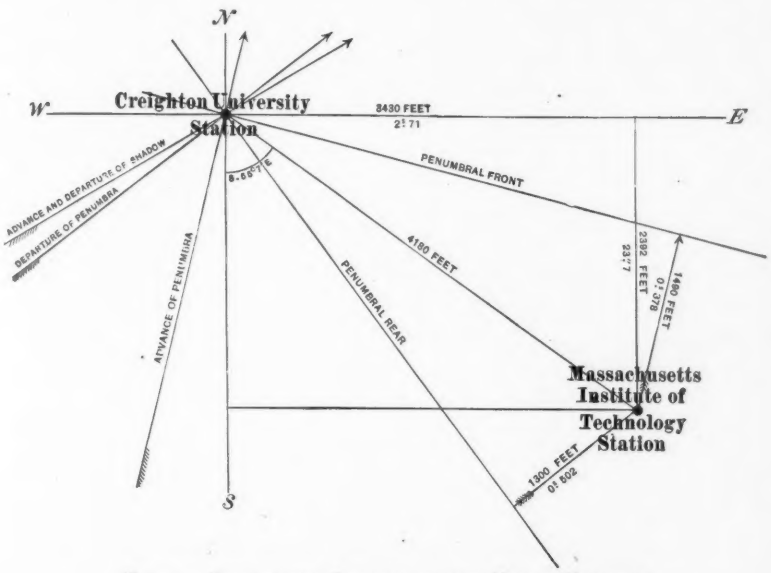

FIG. 2. — COMPARATIVE LOCATION OF THE ECLIPSE STATIONS.

I. The Fundamental Plane. — The Fundamental Plane is the plane, at right angles to the sun's rays, passing through Washington or the centre of the earth.[1] Figure 3 represents the shadow circle upon this plane with its radius equal to 0.00543 at the assumed instant of Greenwich time, $1^h.\ 41.6^m.$, or $7^h.\ 41^m.\ 36.0^s.$, A.M., Central time. O is the centre of this circle, C is the position of the Creighton University station, M that of the Massachusetts Institute of Technology, $G\ H$ and $P\ Q$ are the shadow chords which swept over the stations with F and K as their middle points. The little dot close to the centre of the shadow circle is the position of Washington as given on the eclipse map. The radii marked a, b, a', b', in parentheses, will be referred to afterwards. The numerical values of some of the quantities for both stations are as follows, the notation of the *American Ephemeris* being used throughout :

[1] This is not, strictly speaking, the Besselian Fundamental Plane used in the computation of eclipses, since the latter is normal to the line joining the centres of the sun and *moon* instead of the centres of the sun and *earth*, but as the angle between these two planes was only $6.6''$ at mid-totality, the difference between them is too small to affect my present purpose.

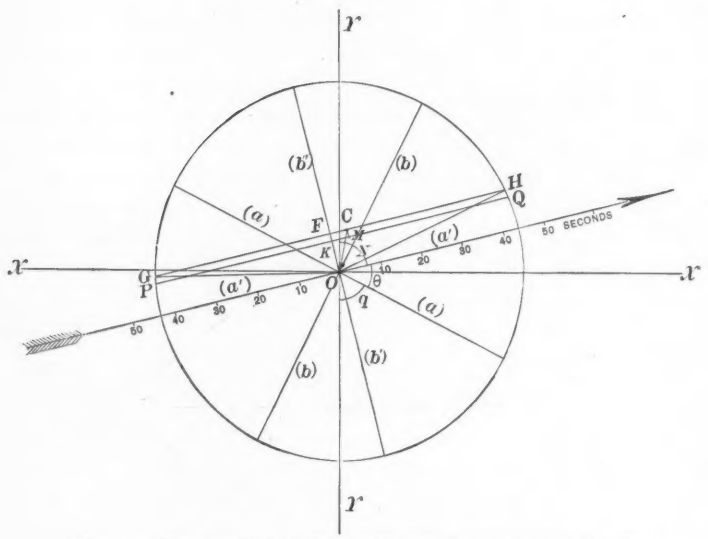

FIG. 3. — THE SHADOW CIRCLE UPON THE FUNDAMENTAL PLANE.

	Creighton University.	Massachusetts Institute of Technology.
$x - \xi$	— 0. 000 22	— 0. 000 23
$y - \eta$	— 0. 00 120	— 0. 00 107
M	190° 23′ 20″	192° 7′ 53″
N	76° 12′ 43″	76° 12′ 43″
$M - N$	114° 10′ 37″	115° 55′ 10″
m	0.00 12200	0 00 10944
n	0.00 74248	0.00 74248
ψ	11° 49′ 40″	10° 26′ 39″

The remaining quantities and the reductions will be given later on.

II. The Washington Horizontal Plane. — 1. Upon this plane the outline of the moon's shadow is an ellipse. The semi-minor axis, b, on Figure 4, is the same as the radius of the shadow circle on the Fundamental Plane (b), on Figure 3, and equal to 0.00543 in terms of the earth's equatorial radius as unity, or 21.560 miles. The semi-major axis $= a = b \sec \zeta = 34.245$ miles, ζ being the sun's zenith distance.

The local azimuth of this major axis is evidently that of the sun N. 88° 31′ 54″ E. The direction of motion, a, of the shadow ellipse

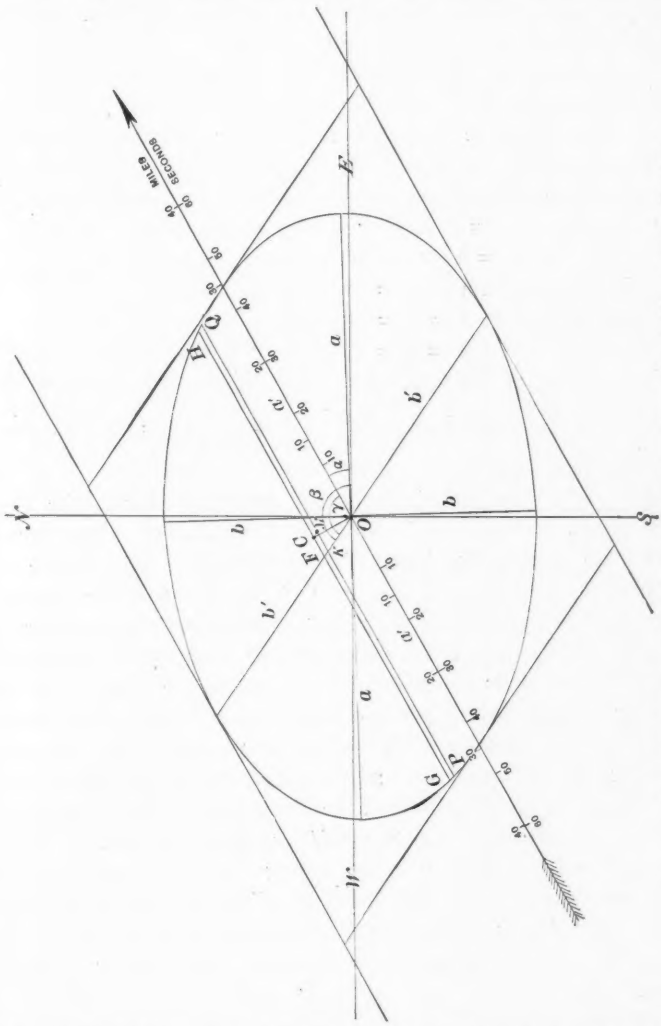

FIG. 4.—THE SHADOW ELLIPSE UPON THE WASHINGTON (GA.) HORIZONTAL PLANE.

with reference to the sun's azimuth, may be found from the formula

$$\tan a = \cos \zeta \tan \theta,$$

in which $\theta = 180° - (V + q) = 40° 25' 44''$ (see Figure 3) is the

angle between the direction of motion of the shadow on the Fundamental Plane with reference to the sun, N is the Ephemeris N, and q is the sun's local parallactic angle. This gives the azimuth of the shadow advance = S. 60° 19′ 24″ W.

The diameter of the ellipse, $2a'$, which lies in the direction of its motion upon the ground, has evidently for its conjugate the line of mid-totality, $2b'$. As these diameters of the ellipse are brought up from the Fundamental Plane where they are at right angles to one another (see Figure 3, where they are marked in parentheses), we find their constants to be

$$a' = b \sin \theta \operatorname{cosec} \alpha = 29.512 \text{ miles},$$
$$b = b \cos \theta \operatorname{cosec} \alpha' = 27.614 \text{ miles},$$

the angle between them $= \gamma = 115° 19' 37''$,
in inclination of a' to $a = \alpha = 28° 12' 30''$,
and of b' to $a = \beta = 143° 32' 7''$.

The velocity of the shadow, v, is $2a'$ divided by the duration of totality upon the central line, that is, $v = \frac{a'}{43.88s.} = 0.67413$ mile or 3,559 feet a second.

As all right lines parallel to a' and b' are projected from the Fundamental upon the Horizontal Plane in corresponding ratios, we find $OF = b' \sin \psi = 5.660$ miles. Then the bearing and distance of C, the Creighton University Station, from O, the centre of the shadow at the assumed moment, $1h.\ 41m.\ 36.0s.$, Greenwich time, together with the length and bearing of OF, determine the triangle FOC, from which we find $FC = 2.6563$ miles which are run by the shadow in $3.94s$. This, therefore, is the correction to the assumed time of mid-totality. $GF = a' \cos \psi = 28.952$ miles, and is run in $42.948s.$, thus giving the instants of the beginning and end of totality at the Creighton station.

In investigating the position of the Massachusetts Institute of Technology station, we find the line CM practically parallel to FO, the divergence being only 0° 6′ 25″, showing that the moments of mid-totality were identical at both stations. The distance of M from C being subtracted from FO and yielding KO, the equation of the ellipse gives us $PK = 29.117$ miles run in $43.193s$. The further results will be seen later.

In this method, as well as in all the others, the dimensions, velocity and direction of the shadow ellipse may be assumed to remain constant for one minute without introducing any sensible error into the computation.

2. Another method of examining the instantaneous constants of the shadow ellipse is to determine the lengths and inclinations of the conjugate diameters from the formulæ

$$\tan a \tan \beta = -\frac{b^2}{a^2},$$

$$a'^2 + b'^2 = a^2 + b^2,$$

$$a'\, b' \sin \gamma = ab.$$

These give

$$a' = 29.62 \text{ miles},$$
$$b' = 27.58 \text{ miles},$$
$$a = 28^\circ\ 12'\ 30'',$$
$$\beta = 143^\circ\ 32'\ 7'',$$
$$\gamma = 115^\circ\ 19'\ 37'',$$
$$v = 0.67504 \text{ mile, or } 3{,}564 \text{ feet a second,}$$

in which the angles are the same as in the previous method, but the lengths of the lines are slightly different.

From the known length of CO and the angles in the triangle FOC, we find $FC = 2.6758$ miles run in $3.964s.$, and $OF = 5.7015$ miles. The formula of the ellipse then gives $FG = 28.980$ miles run in $42.932s.$ Knowing the distance and bearing of M from C, we find the difference of the times of mid-totality to be $0.0024s.$ Then the usual equation of the ellipse gives $KP = 29.144$ miles run in $43.174s.$

3. A third method consists in measuring the necessary data from the government eclipse map. The distance between the mid-totality lines gives the velocity of the shadow equal to 42.2 miles per minute, or 3,712 feet per second, and its direction as from S 60° W. As the duration of totality on the central line was here $1m.\ 27.8s.$, the semi-major axis of the shadow ellipse was found to be $= a' = 30.25$ miles. By measurement parallel to the mid-totality lines, the conjugate semi-minor axis was found to be $= b' = 26.75$ miles, and the angle between the axes $= \gamma = 111^\circ\ 30'$. With these data, the formulæ

$$a'\, b' \sin \gamma = ab,$$

$$a'^2 + b'^2 = a^2 + b^2,$$

$$c = \sqrt{a^2 - b^2},$$

$$e = \frac{c}{a},$$

$$x' = \sqrt{\frac{a^2 - b'^2}{e^2}},$$

$$\cos a = \frac{x'}{a'},$$

$$\beta = \gamma + a,$$

gave
$$a = 33.60 \text{ miles},$$
$$b = 22.42 \text{ miles},$$
$$a = 25^\circ\ 30',$$
$$\beta = 137^\circ\ 0'.$$

4. By using the sun's azimuth and the formula

$$\tan a = \cos \zeta \tan \theta,$$

we find
$$a = 28^\circ\ 23'\ 44'',$$
$$\beta = 143^\circ\ 19'\ 10'',$$
$$\gamma = 114^\circ\ 55'\ 26'',$$
$$a = 33.97 \text{ miles},$$
$$b = 21.56,$$
$$a' = 29.34,$$
$$b' = 27.53.$$

The further reduction of the results in these two last cases is by the same method as in the second solution. But as measurements on a map cannot compete in accuracy with computed values, no use has been made of these results except as checks upon the computation.

COMPARISON OF THE RESULTS OF THE METHODS OF REDUCTION.

	Creighton University.			Massachusetts Institute of Technology.		
	Fund. Plane.	Horizontal Plane.		Fund. Plane.	Horizontal Plane.	
		1.	2.		1.	2.
Assumed Central Time of Mid-totality. $7h.\ 41m.$	$s.$ 36 00	$s.$ 36 00	$s.$ 36.00	$s.$ 36.00	$s.$ 36.00	$s.$ 36.00
Time to run FC and $KM = +t_2$	4.04	3.94	3.96	3.87	3.94	3.96
Mid-totality. $7h.\ 41m.$	40 04	39.94	39 96	39.87	39.94	39.96
Time to run FG and $PK = \pm t_1$	42.95	42.95	42.93	43.15	43.19	43.17
Beginning of totality. $7h.\ 40m.$	57.09	56.99	57.03	56 72	56.75	56.79
End of totality. $7h.\ 42m.$	22.99	22.89	22 89	23.02	23.13	23.13
Reduction of M. I. T. to C. U. { Beginning,	....	....	....	+0.37	+0.24	+0 24
Reduction of M. I. T. to C. U. { End	....	....	....	−0.03	−0.24	−0.24
Duration of totality	85.90	85.90	85.86	86.30	86.38	86.34
Difference	....	....	....	−0.40	−0.48	−0.48

As the *American Ephemeris* gives its data only to five decimal places, differences of tenths of a second in the reduction can hardly be relied upon. However, giving the reductions computed upon the Fundamental Plane half the weight of either of those obtained from the Horizontal Plane, we find that we must add + 0.3*s.* and — 0.2*s.* to the observed times at the Massachusetts Institute of Technology station in order to reduce them to those observed at the Creighton University station, and hence for all four contacts the reductions are

I.	II.	III.	IV.
+0.4*s.*	+0.3*s.*	—0.2*s.*	—0.5*s.*

The Observations of the Contacts made by the Massachusetts Institute of Technology Reduced to the Creighton University Station.

The *Technology Quarterly* quoted above (September, 1900), on pages 171 and 172, gives the times of the contacts as observed by Mr. Hosmer and Professor Robbins. As these are expressed in Washington local mean time, we add to them the Greenwich longitude of the place, 5*h.* 30*m.* 56.2*s.*, and then subtract 6*h.* 0*m.* 0*s.*, in order to reduce them to Central time, and lastly add also the above-computed reductions in order to reduce them to the Creighton University station. The results are then as follows:

George L. Hosmer.	I.	II.	III.	IV.
	h. *m.* *s.*	*h.* *m.* *s.*	*h.* *m.* *s.*	*h.* *m.* *s.*
Washington time	7 2 22.7	8 9 52.0	8 11 18.2	9 23 26.9
Greenwich longitude	+5 30 56.2	+5 30 56.2	+5 30 56.2	+5 30 56.2
Red. to Central time	—6 0 0.0	—6 0 0.0	—6 0 0.0	—6 0 0.0
Red. to C. U. Station	+ 0.4	+ 0.3	— 0.2	— 0.5
Central time at C. U. Station . .	6 33 19.3	7 40 48.5	7 42 14.2	8 59 22.6

Arthur G. Robbins.	I.	II.	III.	IV.
	h. *m.* *s.*	*h.* *m.* *s.*	*h.* *m.* *s.*	*h.* *m.* *s.*
Washington time	7 2 16 4	8 9 53.1	8 11 18.4	9 28 16.1
Greenwich longitude	+5 30 56 2	+5 30 56 2	+5 30 56 2	+5 30 56 2
Red. to Central time	−6 0 0.0	−6 0 0 0	−6 0 0.0	−6 0 0.0
Red. to C. U. Station	+ 0.4	+ 0 3	− 0.2	− 0.5
Central time at C. U. Station . .	6 33 13.0	7 40 49.6	7 42 14.4	8 59 11.8

GENERAL COMPARISON OF COMPUTED AND OBSERVED TIMES.

Central Times.	Contacts. I.	Contacts. II.	Contacts. III.	Contacts. IV.	Mid-totality.	Duration of totality.	Duration of whole eclipse.
	h. *m.* *s.*	*h.* *m.* *s.*	*h.* *m.* *s.*	*h.* *m.* *s.*	*h.* *m.* *s.*	*m.* *s.*	*h.* *m.* *s.*
Computed	6 33 17.0	7 40 57.1	7 42 23.0	8 59 29.8	7 41 40.0	1 25.9	2 25 72.8
Observed by Rigge . .	18.3	50.0	16.0	18.6	33.0	1 26.0	60.3
Observed by Hosmer . .	19.3	48.5	14 2	22.6	31.4	1 25.7	63.3
Observed by Robbins .	13.0	49.6	14 4	11.8	32.0	1 24.8	58.8
Computed Rigge .	−1.3	+7.1	+7.0	+11.2	+7.0	−0 1	+12.5
Minus Hosmer,	−2.3	+8.6	+8.8	+ 7.2	+8.6	+0.2	+ 9.5
Observed Robbins,	+4 0	+7.5	+8.6	+18.0	+8.0	+1.1	+14.0
Hosmer — Rigge . . .	+1.0	−1.5	−1 8	+ 4.0	−1.6	−0.3	+ 3.0
Robbins — Rigge . . .	−5.3	−0.4	−1.6	− 6 8	−1.0	−1.2	− 1.5
Hosmer — Robbins . .	+6.3	−1.1	−0.2	+10.8	−0.6	+0.9	+ 4.5

Creighton University,
Omaha, Neb., January 1, 1901.

ENGINEERING SOCIETY
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CHANGES THAT TAKE PLACE IN THE BACTERIAL CONTENTS OF WATERS DURING TRANSPORTATION.

By GEORGE C. WHIPPLE.

Bacteriologists are agreed that in order to obtain the most accurate determination of the number of bacteria in a sample of water the plating should be done at the time of collection. It was early observed that if this were delayed the resulting count would be different from that obtained by immediate plating. Unless the sample was kept on ice or in a cool place, the number of bacteria generally increased on standing, the increase in 24 hours being sometimes several hundred per cent. Even when kept on ice the number of bacteria did not remain constant, but sometimes increased, and occasionally decreased. In the vast majority of cases in actual practice immediate plating is an impossibility. A knowledge of the changes that take place in the bacterial contents of waters when kept for various lengths of time under different conditions is, therefore, a matter of great importance, and in view of its importance, the experimental evidence upon the subject is surprisingly meager.

Dr. E. O. Jordan[1] and Mr. E. E. Irons have pointed out that when samples of water are stored in ice, the number of bacteria sometimes decreases and sometimes increases during the first two days after collection, and that this can be explained, in part at least, by the initial temperature of the water. During the summer the change from the initial temperature of surface waters to the temperature of the ice box is ordinarily considerable, and the shock produced by the sudden cooling causes a reduction of vitality, or possibly death, to some of the bacteria present, while during the winter this change in temperature is less marked.

In general, the observations of the author tend to corroborate these statements, but experiments seem to show that many other

[1] E. O. Jordan and E. E. Irons. Notes on Bacterial Water Analysis. Reports of American Public Health Association, Vol. XXV, p. 564.

factors enter into the problem. For example, it has been found that whether the sample is stored in ice or at room temperature, the number of bacteria first diminishes and later increases. This is illustrated in the following table:

Sample.	Initial temperature.	Temperature of incubation of sample.	Number of Bacteria Per c.c.				
			Initial.	After 3 hours.	After 6 hours.	After 24 hours.	After 48 hours.
A . .	7.6° C.	17.0° C.	260	215	230	900	27,000
B . .	7.6°	17.0°	260	245	255	720	10,850
C . .	7.6°	12.5°	260	270	231	600	2,790
D . .	7.6°	12.5°	260	270	245	710	1 800
E . .	7.6°	2.4°	260	243	210	675	1,980
F . .	7.6°	2.4°	260	235	270	560	1,980
G . .	11.0°	12.8°	77	55	58	101	10 250
H . .	11.0°	12.8°	77	53	74	87	2,175
I . .	11 0°	23.6°	77	51	52	11,000	41,400
J . .	6.7°	20.0°	430	375	245	...	385,000[1]
K . .	6.7°	20.0°	430	345	405	....	750,000[1]
L . .	23.2°	23.0°	510	340	230	8,000	20,000
M . .	23.2°	2.5°	525	300	220	380	2,200

[1] 0.0005 per cent. peptone added to the water.

In order to determine whether this reduction was due to the death or to the reduced vitality of the bacteria present, whether to the aggregation of the bacteria, or to their attachment to the sides and bottom of the sample bottle, the following experiments were made. Fifty cubic centimeters of tap water were put into a 2-ounce chemical salt-mouth bottle, and allowed to stand in the 20° incubator for 3 hours. The water originally contained 99 bacteria per c.c., this figure being the average of 5 plates. At the end of 3 hours the bottle was thoroughly shaken and 2 plates made, the resulting counts being 84 and 87. The water was then poured out, the bottle drained, and 50 c.c. of sterile distilled water added. After shaking, 2 plates were

made as before, the counts being 1 and 2 respectively. The distilled water was then poured out, leaving behind only those bacteria that had become attached to the glass; 10 c.c. of standard nutrient gelatin were then put in the bottle and a roll-culture made. The number of colonies that developed was 84, or approximately 1.5 for each cubic centimeter of water. At the end of three hours, therefore, the sample contained $\frac{84+87}{2} + \frac{1+2}{2} = 87$ per c.c., or 12 per c.c. less than the original number. A second sample collected at the same time was kept 6 hours in the incubator, and treated in a similar manner. At the end of this period the water contained 56 bacteria per c.c., and 118 were obtained by the roll-culture, equal to more than 2 per c.c. of the original water. A second experiment of the same kind gave the following results:

	Sample A.	Sample B.	Sample C.	Sample D.
Number of bacteria at time of collection . . .	255	275	330	280
Number of bacteria after 5 hours	225	220	...	...
Number of bacteria after 24 hours	...	...	25,000	30,000
Number of bacteria in distilled water used for washing	1	1	230	270
Number of bacteria in bottle, by roll culture . .	365	296	37,000	30,000

These experiments indicate that the decrease in the number of bacteria immediately after collection cannot be explained by loss from precipitation upon the glass, but they also indicate that the error introduced by this cause may be important if the sample is allowed to stand for a considerable time.

There seemed to be a possibility that the decrease in number might be due to the aggregation of the bacteria upon standing with consequent reduction in the number of colonies. The following experiment apparently disproves this. Two samples of tap water were collected in 2-ounce bottles, and incubated for 3 hours at the initial temperature, 22° C. Bottle *A* was almost full; bottle *B* was about one-third full. From each of these bottles duplicate samples were withdrawn after giving ten gentle shakes, and again after shaking vigorously two hundred times.

Sample.	Number of Bacteria Per c.c.	
	Initial.	After 3 hours.
A. Shaken ten times	590	380
A. Shaken two hundred times	580	360
B. Shaken ten times	645	370
B. Shaken two hundred times	610	390

The decrease in the number of bacteria after collection in small bottles seems, therefore, to be due to the effect of changed environment upon the bacteria. It has been observed that when a sample is kept at its initial temperature, the change in the bacterial contents is less than when kept at a different temperature. It has been also noticed that this change was somewhat greater in samples taken from service taps where the bacteria had been under pressure, than in samples taken from the surface of a reservoir. Further, it is a matter of common observation that samples plated at the time of collection show a greater number of different species than the same samples plated 24 hours after collection.

The character of the bottle has an effect upon the rapidity of growth of bacteria. This fact was observed by the author several years ago, but its importance was not appreciated until the following experiments were made.

Tap water was collected in four bottles and incubated for 72 hours at 18°. The initial temperature of the water was 12.5° C. Sample *A* was collected in a 2-quart glass-stoppered sterilized bottle, and the bottle was completely filled, leaving no air space. Sample *B* was collected in a similar bottle which was but half filled. Sample *C* was taken in a 2-ounce chemical salt-mouth bottle completely filled, and sample *D* in a 2-ounce bottle half filled. Duplicate plates were made from each bottle at intervals with the following results:

Sample.	Number of Bacteria Per c.c.			
	Initial.	After 24 hours.	After 48 hours.	After 72 hours.
A. 2-quart bottle, completely filled	99	85	161	195
B. 2-quart bottle, half filled	99	90	570	705
C. 2-ounce bottle, completely filled	99	...	...	6,450
D. 2-ounce bottle, half filled	99	285	850	125,000

A second experiment made in the same way except that the water samples were incubated at 37° instead of at 18° C., gave the following results:

Sample.	Number of Bacteria Per c.c.	
	Initial.	After 24 hours.
A. 2-quart bottle, completely filled	160	1,900
B. 2-quart bottle, half filled	160	2,800
C. 2-ounce bottle, completely filled	160	68,000
D. 2-ounce bottle, half filled	160	72,000

In the third experiment bottles of various sizes were used, and the incubation was made at 13° and at 24° C., these being the averages of the observed temperatures. In order that the temperatures should be the same for each series, the bottles were kept in tanks filled with water, the necks of the bottles projecting above the water. In all cases the bottles were half full. The results are given in the following table.

Sample.	Bottle.	Temperature of incubation.	Number of Bacteria Per c.c.					
			Initial [1]	After 3 hours.	After 6 hours.	After 12 hours.	After 24 hours.	After 48 hours.
A.	1-gallon . .	13°	77	63	65	47	42	175
B.	2-quart . .	13°	77	59	63	60	45	690
C.	1-quart . .	13°	77	63	63	47	46	325
D.	1-pint . . .	13°	77	57	61	36	38	630
E.	2-ounce . .	13°	77	55	58	47	101	10,250
F.	1-gallon . .	24°	77	81	97	275	290	300
G.	2-quart . .	24°	77	92	59	62	180	250
H.	1-quart . .	24°	77	84	77	46	340	900
I.	1-pint . . .	24°	77	51	46	100	2,950	7,020
J.	2-ounce . .	24°	77	51	52	145	11,000	41,400

[1] Average of five plates.

A comparison was then made between the growth in 2-ounce bottles and in 250 c.c. flasks plugged with cotton, the samples being incubated at three different temperatures.

Sample.	Receptacle.	Temperature of incubation.	Number of Bacteria Per c.c.				
			Initial.[1]	After 3 hours.	After 6 hours.	After 24 hours.	After 96 hours.
A.	250 c.c. flask, filled to neck . . .	2.5°	260	235	270	560	1,980
B.	250 c.c. flask, half filled	2.5°	260	285	295	490	2,070
C.	2-ounce bottle, completely filled . .	2.5°	260	243	210	675	1,980
D.	2-ounce bottle, half filled	2.5°	260	275	255	595	12 600
E.	250 c.c. flask, filled to neck	12.5°	260	270	231	600	2,790
F.	250 c.c. flask, half filled	12.5°	260	295	280	705	1,890
G.	2-ounce bottle, completely filled . .	12.5°	260	270	245	710	1,800
H.	2-ounce bottle, half filled	12 5°	260	285	260	670	18,000
I.	250 c.c. flask filled to neck	17.0°	260	245	255	720	10,850
J.	250 c.c. flask, half filled	17.0°	260	255	290	1,510	....
K.	2-ounce bottle, completely filled . .	17.0°	260	215	230	900	27,000
L.	2-ounce bottle, half filled	17.0°	260	258	258	1,800	37,800

[1] Average of five plates.

Comparisons were next made in bottles of one size containing different amounts of water. The bottles had a capacity of 120 c.c. In this experiment 0.0005 per cent. of peptone was added to hasten the growth. The incubation was made at a temperature of 19.5° C. The following results were obtained:

Sample.	Amount of water in cubic centimeters.	Depth of water in centimeters.	Number of Bacteria Per c.c.	
			Initial.	After 36 hours.
A.	120[1]	15.0	430[2]	385,000
B.	100	12.5	430	510,000
C.	50	6.3	430	559,000
D.	20	2.5	430	656,000

[1] Bottle full.

[2] Average of five plates.

These experiments seem to justify the following conclusions: After the collection of a sample in either a large or a small bottle, there is a slight reduction in the number of colonies that can be obtained upon the gelatin plate, due apparently to the effect of changed environment upon the bacteria present. This reduction is perhaps somewhat greater when a small volume of water is collected, as its temperature change is naturally more rapid. The subsequent growth takes place more rapidly in a small bottle than in a large bottle, and more rapidly when the bottle is but partially filled than when it is completely full. With bottles of the same size the growth is more rapid in small volumes of water than in large volumes. The explanation of this is not wholly clear, but undoubtedly the supply of oxygen is an important factor, and it is probably the controlling factor.

These results have a practical bearing upon the procedure of the water analyst. They show first the great advantage of plating immediately after collection. They show that bottles larger than the customary 2-ounce salt-mouths should be used if the samples are to be kept long before plating, and that the bottles should be filled almost full. (It is necessary to leave a small amount of air space for expansion or contraction due to temperature changes.) But they also show that if the plating is made within a few hours of collection, the character of the bottle is practically immaterial, provided of course, that it is perfectly clean and sterilized.

During transportation, samples of water are usually subjected to more or less jolting, and the water is therefore kept in a state of agitation. In order to determine what effect gentle agitation has upon bacteria, the following experiment was made:

A 250 c.c. sterilized flask was partially filled with the sample and floated near the surface of water in a beaker. The water in the beaker was then kept in a state of commotion by blowing in air from a Richards pump. The rising bubbles caused the flask to bob about in a lively manner, keeping its contents continually in motion. The apparatus was placed in the incubator, the air tube being passed through one of the ventilating holes. A second flask that contained an equal amount of the sample was put in a second beaker and kept by the side of the first in order that temperature conditions might be the same. This flask was kept quiet. The incubator maintained an average temperature of 20°, and the atmosphere was saturated with

moisture. The initial temperature of the sample was 9.0° C. At intervals duplicate plate cultures were made from the two flasks. The following were the results:

Sample.	Number of Bacteria Per c.c.				
	Initial.	After 2 hours.	After 18 hours.	After 24 hours.	After 42 hours.
Quiet flask	225	193	365	445	1,690
Agitated flask . . .	212	186	340	385	1,120

A duplicate experiment gave similar figures. The temperature of the incubator was 23.5° C.

Sample.	Number of Bacteria Per c.c.		
	Initial.	After 5 hours.	After 48 hours.
Quiet flask	141	190	5,000
Agitated flask	141	146	3,100

The experiment was then modified by putting the samples into sterilized, wide-mouthed, 2-ounce bottles and blowing air into one of them. The air from a Richards pump was made to pass through a double cotton filter and through a sterilized rubber tube connected with a glass tube that entered the bottle. A T connection permitted a part of the air to be passed into a third bottle filled with sterilized distilled water, and run as a blank to determine whether the air carried any bacteria into the sample. The flow of air into the bottle that contained the sample was regulated so that about two bubbles per second rose in the water. The apparatus was placed in the incubator where the average temperature was 23.0° C. The following results were obtained:

Sample.	Number of Bacteria Per c.c.		
	Initial.	After 4 hours.	After 20 hours.
Quiet sample	240	235	1,250
Aerated sample	240	225	625
Aerated blank sample	0	...	2

In order to determine the effect of more violent shaking, a sample of water in a 2-ounce bottle packed in a tin box was attached to the piston rod of a pumping engine, while a duplicate sample was kept quiet near by. Both bottles were but partially filled. The engine was pumping at the rate of 60 strokes per minute, and the length of the stroke was about 2 feet. The temperature of the room varied from 21.0° to 26.0° C.

Sample.	Number of Bacteria Per c.c.	
	Initial.	After 18 hours.
Quiet bottle	200	8,000
Bottle shaken on the engine	200	140

A second experiment was made in a similar manner, but 0.01 per cent. of pepton was added to the water to hasten the development of the bacteria.

Sample.	Number of Bacteria Per c.c.	
	Initial.	After 18 hours.
Quiet bottle	78	1,900,000
Bottle shaken on the engine	70	342,000

These experiments show that agitation exercises a retarding influence upon the multiplication of bacteria, but that the slight shaking that water samples are liable to receive for a few hours during transmission is practically of little importance in its effect upon quantitative determinations of the bacterial contents.

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THE PRECISION OF THE SLIDE RULE.

By LOUIS DERR, S.B., M.A.

As employed in engineering calculations, the ordinary 10-inch slide rule is commonly considered accurate to one-half of 1 per cent., and for work of greater precision some other method of computation is thought essential. Repeated trials, however, have brought to the writer the conviction that this limit is too low. With care a good rule will give much more accurate results.

In support of this contention the following example is adduced. The data were laboratory observations of four variable quantities, a, b, c, d, and fifteen sets of observations were taken. It was required to compute the products ab and cd, and the ratios $ab : cd$ for each set. These were worked out on the different scales of a 10-inch and a 20-inch slide rule, and the results compared with those obtained by using two many-figure calculating machines of different patterns. The quantity a had four significant figures, b and c three, and d either three or four. The computation by logarithms would therefore be made with a four-place table.

When simple products or quotients are desired, the lower scales of the slide rule are naturally used for greater accuracy; but when a compound fraction of the form $abc../..pqr..$ is to be evaluated, the upper scales are generally more convenient. This is because the slide must often be shifted through its whole length when the lower scales are used, even though the sequence of operations is carried out to the best advantage. If intermediate products are desired, it is usually necessary to compute them separately, and if the remainder of the calculation is obtained from these values, the additional uncertainties of reading and resetting affect the result much more than if the computation were carried through at a single operation. This is illustrated by (3) of the table below, which should be compared with the figures just above in the 20-inch column. In this respect the calculating machine has a decided advantage over the rule, for the inter-

mediate values can be read off and recorded as they appear on the figure wheels.

It is difficult to measure the comparative speed of the calculating machine and the slide rule, chiefly because the character of the operations is totally different. It follows from this that for a trustworthy measure of speed the computer should be equally skilled in the use of both machine and rule, and this can hardly be assumed as true for the average case. Tests of this kind also often omit an essential factor—the time required to record the result. Broadly speaking, the writer has observed that a computation carried out to a given number of places by rule will require half again as much time by machine. To get an additional place of figures by machine, twice as much time must be taken as in the first case by rule. This result, though not necessarily valid for all observers, testifies at any rate to the extreme rapidity of slide-rule computation, since it is a well-established fact that on four- or five-figure work machine computation requires from 35 per cent. to 50 per cent. of the time required with logarithms.

The following table summarizes the results of five series of precision tests. In the last two, the quantities m, n, p, q, contained five significant figures each. For such data the 10-inch rule is clearly inadequate, and only the lower scales of the 20-inch rule were used.

TABLE.

ERRORS OF COMPUTATION BY SLIDE RULE, IN FRACTIONS OF 1 PER CENT. OF THE QUANTITY COMPUTED.

	10-inch rule.	20-inch rule.
(1) Product ab of two four-place numbers, on lower scales (2 settings, 1 reading):		
Average error	0.041	0.026
Greatest errors	0.157 and 0 091	0.069 and 0 069
(2) Ratio $ab : cd$, on upper scales (4 settings, 1 reading):		
Average error	0.133	0.062
Greatest errors	0.349 and 0.226	0 181 and 0.135
(3) Product ab divided by product cd, all computed separately on lower scales (6 settings, 3 readings):		
Average error	0.079	
Greatest errors	0 198 and 0 177	
(4) Product mn of two five-place numbers, lower scales:		
Average error		0 037
Greatest errors		0.096 and 0.090
(5) Ratio $mn : pq$, on lower scales (average $4\frac{1}{2}$ settings, 1 reading):		
Average error		0.046
Greatest errors		0 167 and 0.130

Of the computations entering the above table, five were exact, 63 showed a negative error, and 68 a positive error.

If unconfirmed, a number of trials not greater than the above would hardly warrant very definite conclusions; but since these are only typical of hundreds in the writer's experience, it seems legitimate to make the following deductions:

(1) For short calculations the upper scale of the 10-inch rule is reliable to one-quarter of 1 per cent. The lower scale is better than one-fifth of 1 per cent., and may generally be used instead of a four-place logarithm table. It should be observed that the upper scale of the 20-inch rule, and the lower scale of the 10-inch rule are graduated alike.

(2) For short calculations the lower scale of the 20-inch rule is reliable to one-tenth of 1 per cent., and may be used instead of a five-place logarithm table.

(3) If five places of figures are to be obtained, and the intermediate products are required, the 20-inch rule is not much faster than a machine, and is vastly more fatiguing.

In applying the above conclusions to practice, two things must be prescribed: the rule employed must be accurate, and the computer should be practiced in the estimation of tenths. Other than this, no unusual skill is required, nor is any claimed in the above tests.

A NEW ERA IN INTERIOR LIGHTING.

By CHARLES L. NORTON.

We have so long given to window glass the task of keeping out the wind and rain, while letting the light and warmth of the sky enter, that the intrusting of another task to this universal detail of our structures is a step which interests the whole community. The window is henceforth to be not only an opening through which light may enter, but a medium for sending the light in the direction in which it is most desired. Except where it is necessary to have windows through which to look, conditions of economy will soon forbid the general use of plane glass. The age of plane glass has passed, to be succeeded by an age of scientific diffusion of light.

If our windows be of plane glass, the best and brightest light in the room is on the floor near the window, and it is here largely absorbed and lost. If, however, we interpose in the beam of light as it passes through the window a suitable diffusing medium, we may divert the light from its original downward direction into others where it will be more effective. The ribbed, corrugated, ground, and figured glasses now coming into common use are diffusing media for accomplishing this end, and it is to them and to their uses that it is the purpose of this paper to call attention.

In the year 1883, Mr. Edward Atkinson reported the method of constructing English cotton factories to his associates, calling attention to the use of rough-plate or hammered glass for glazing factory windows, it being claimed that a better light was distributed within, a claim which appeared to him to have a sound basis. Reasoning upon the subject, he first proposed to make prismatic glass with a view to deflecting and diffusing the light, but finding that such glass would be very costly, and subject to some other objections, he turned his attention to the types of glass already in use, causing photographic images to be made of the diffused light. These images showed that the common ribbed glass, in use for obstructing vision, also diffused

light in a most effective way. He published the facts, and soon after many mills and works were either newly glazed or reglazed with ribbed glass. A discussion having arisen on the relative merits of ribbed and prismatic glass, it became necessary to bring the matter to a scientific basis.

In 1894 he brought the matter to me, and we have just completed a series of experiments begun at that time, to determine just what gain would arise from the use of the new window glass in a large way, as in the windows of mills, schoolhouses, and public buildings.

The extent of our knowledge on the matter in 1894 was certainly not large, and very few of my acquaintances of scientific bent believed in the practicability of any such scheme for improving the present conditions of lighting. I am quite ready to confess that I was so sure that the insertion of a sheet of ribbed or corrugated glass in a window would be attended by a loss of illumination, that I designed my photometer to measure negative instead of positive quantities, and had the pleasure of rebuilding it.

The materials available for use as diffusing media in windows are of two distinct types: first, the corrugated and figured sheet glass; and second, the carefully designed and moulded prisms. Figures 1, 2, and 3 indicate the distribution of light in a small room with the window glazed in the different ways. After considerable study we came to the conclusion that the only data that would be of value to us in forming conclusions as to the practical utility of the diffusing glasses must be obtained from the examination of a large room lighted by a single window, in which the several glasses might be placed in rapid succession. The outdoor surroundings, the amount of exposed sky, the angular height of obstructions and the depth of the reveal over the window may be altered by means of suitable curtains. The method of procedure followed in the recent tests for the Factory Mutual Fire Insurance Companies, under the supervision of Mr. Edward Atkinson, was as follows:

All the makers of diffusing glasses of whom we could find trace were requested to send samples if they desired to participate in the test. Nearly a score of samples were received in response to our circular letter, and a few samples were purchased.

The Physics Lecture Room in the Walker Building of the Massachusetts Institute of Technology, was placed at our disposal by the Institute, and it proved to be in every way a suitable place in which

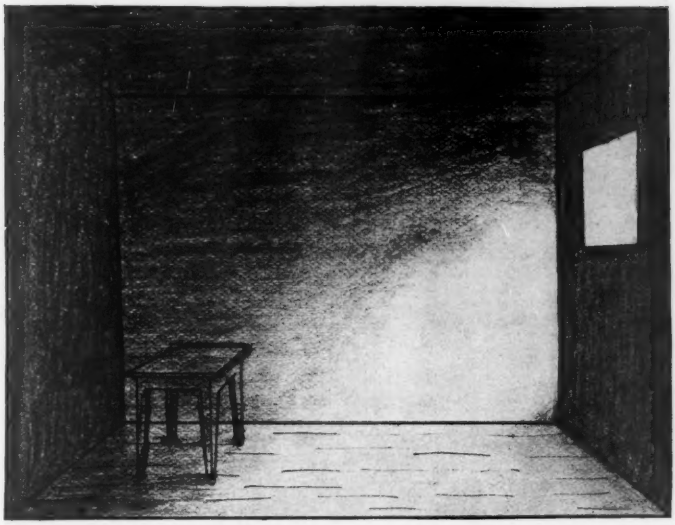

FIG. 1. — SKETCH SHOWING THE DISTRIBUTION OF THE LIGHT IN A SMALL ROOM WITH A WINDOW OF PLANE GLASS

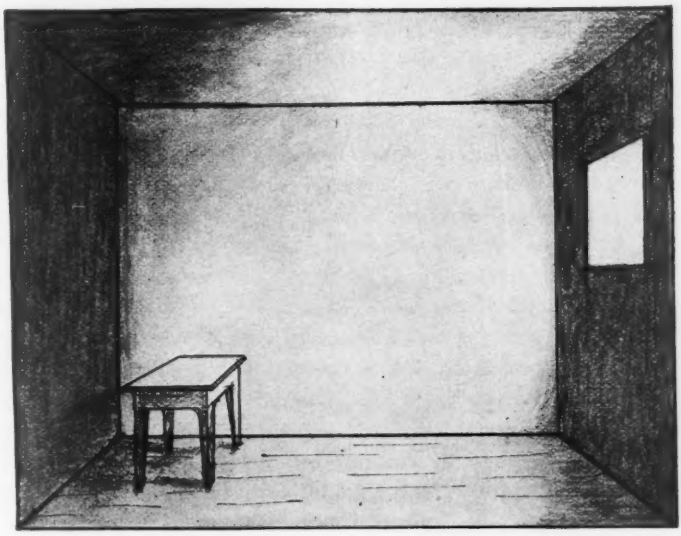

FIG. 2. — SAME AS FIGURE 1, WITH FACTORY RIBBED GLASS

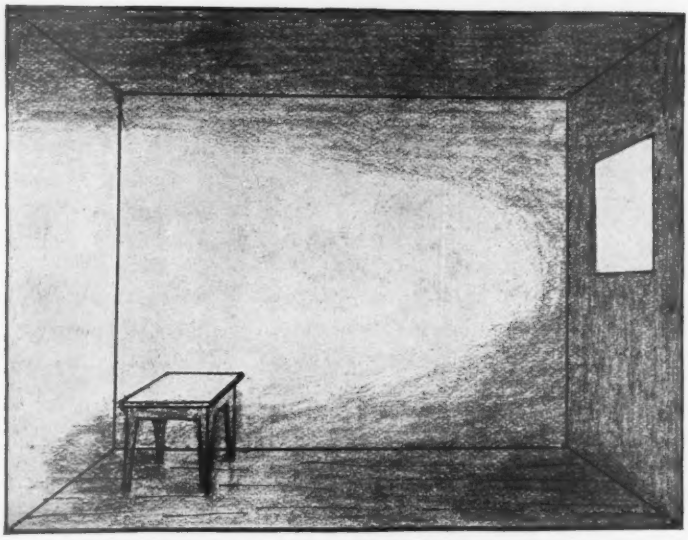

FIG. 3. — SKETCH SHOWING THE DISTRIBUTION OF LIGHT IN A SMALL ROOM, WITH A WINDOW OF PRISMATIC GLASS.

to make the tests. All openings by which light might enter the room were closed, except one window on the west side. This window was 12 inches square, and about 8 feet from the floor. The specimens of glass were inserted in the window in rapid succession, and photometric comparisons of the intensity of the light in the different cases were made. With each specimen the intensity of light was measured in a horizontal plane at the height of the table tops, observations being taken at stations 10 feet apart over the entire floor. The room was 50 feet wide and 40 feet deep.

The general conclusions to be drawn from the observations are: first, that in rooms of from 15 to 30 feet in depth, the ribbed or corrugated glasses will give an increase in the effective light at the level of the table tops, of from 200 to 500 per cent. Some of the prisms will do as well, but they are usually found to give too little diffusion in small rooms, especially where the windows are few and small.

Second, in rooms from 50 to 100 feet deep, the ribbed or corrugated glasses will often give an increase of effective light of fifteen times the original amount, and the prisms, especially when set in canopies, will increase the light in some cases to fifty times its origi-

nal effective strength. The determining factors in the case are the depth of the room, the angle of exposed sky, and the number and size of the windows. Stated broadly, the use of suitable prism canopies should make a basement as well lighted as a second story above it, glazed with plane glass.

The varieties of glass available for this work of diffusion are constantly increasing in number, and decreasing in cost. Among the less expensive are the ribbed or corrugated glasses. These may be had in different degrees of fineness of corrugation, in several thicknesses, and with the corrugations upon one or both sides. The finely corrugated glass with twenty-one ribs to the inch, has been known for several years as Factory Ribbed Glass, the name having been suggested by Mr. Atkinson. It is more sharply rolled than the glass with larger corrugations, and gives a better projection into deep rooms, but it accumulates dirt more rapidly than the coarser glasses.

There are almost numberless figured glasses, with a design of some sort worked in low relief on one side of the sheet. These act as excellent diffusing media in small rooms, but do not pitch the light up toward the horizontal enough to be effective in deep rooms.

The prisms made by three of the large companies were tested, though one sample came to hand too late to be given a complete series of tests. One make of prisms consists of sharp, carefully moulded triangular prisms, usually in tiles or plates about 4 inches square, and about $\frac{3}{8}$ of an inch thick. These are made of many different angles, and are installed only after careful consideration of the conditions under which the prisms are to be used. They are very satisfactory devices for projecting light in any desired direction in a room, with absolute certainty and with very little diffusion. A second prism differs from the first merely in that the lower surface of the prisms is curved instead of plane, giving a cross section which is substantially that of the lower half of the rib of the Factory Ribbed Glass. This gives a wider diffusion, but less concentration of the beam where it is desired to throw it in one direction, as is often the case in deep rooms. The third make of prisms is quite similar to the first type, except that the outer side, or back of the prism plate, is not plane but slightly sinuous in outline. Enlarged sections of the different diffusing glasses are shown in Figure 4.

The intensity measurements were made with a modified Cornu photometer, which served to compare the brilliancy of a piece of

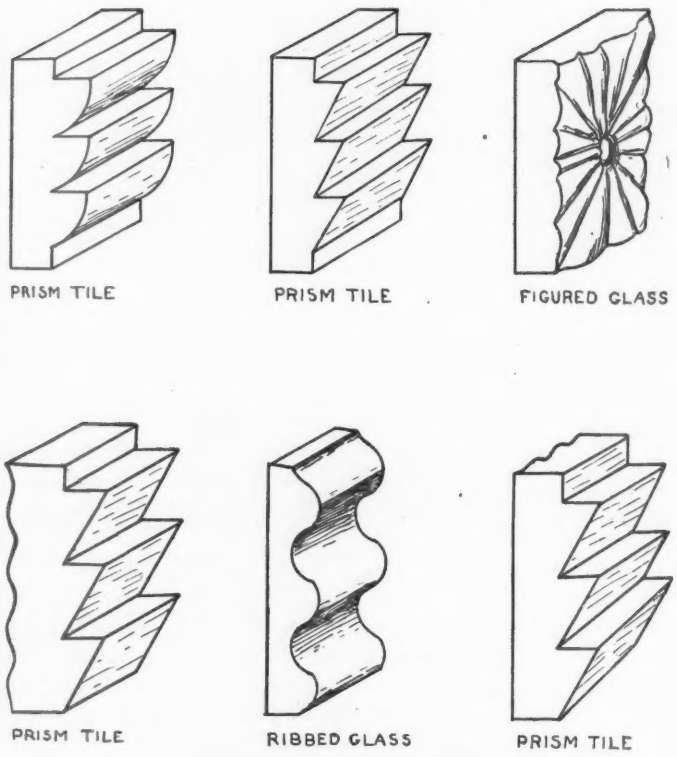

FIG. 4. — SOME DIFFUSING GLASSES.

white porcelain placed at the window with that of a second piece which could be moved to any desired point in the room. This method gave measurements which were expressed in percentages of the intensity of the light at the window, and were wholly independent of the strength of the light at the window at the moment of comparison. A radial arm, 15 feet long, centered just below the window, was also used to carry the white screen, but it was found that the results obtained with an arm of this length were of little value in furnishing data on the action of the different diffusing glasses in rooms of a depth greater than 15 feet. The reason for the apparent discrepancy between the observed value of the intensity at the back of the room 50 feet deep, and the values computed from the measurements made at a distance of 15 feet from the window, lies in the fact that a very

considerable and variable amount of light is reflected from the ceiling. It should be borne in mind that the light from the upper sash usually strikes the ceiling at a small angle, and that the reflecting power of even a dingy and rough ceiling is considerable at small angles. The glass which throws the strongest beam directly toward the back of the room may not furnish as satisfactory an illumination there as one which throws a more feeble beam directly toward the back wall, but adds a considerable amount to it by reflection from the walls and ceiling. It was therefore deemed better to measure the intensity of the light at a sufficient number of stations, and make an intensity map of the room for each kind of glass.

The examination of the different samples of glass showed at once that their usefulness lay largely in different fields, as was suggested above. In shallow rooms now fairly well lighted, the figured glasses give a soft, well-diffused light with an absence of glare and a material strengthening of the light in the rear portion of the room. As we study rooms 30 feet or so in depth, we find the figured glass gives too little light near the back of the room. Evidently something is here needed to throw the light further up toward the horizontal, as well as to give a nearly hemispherical diffusion, and the Factory Ribbed Glass has here proved its value. The action of this glass is very interesting to me. It exists, not because of its diffusing properties, but because it is an obstruction to vision without many of the faults of the ground and painted glasses which were much used earlier. It was never designed to be a thorn in the flesh of the makers of prismatic glass, yet such, I fear, it has been for some time past. The fact that a cheap rolled glass can be of merit as a diffusing medium seems to be beyond the belief of the makers of the carefully moulded prisms. The relative efficiency of the rib and the prism is largely dependent upon the size of the sky angle to which they are exposed, and the depth of the room which they are to light. If the light came from one point in the sky, and was to be used at only one point in the room, the angular prism of precise form would unquestionably be of the greatest value, and it is in the cases where those conditions are most nearly true that the prism finds its greatest field of usefulness. But in cases where the light comes from a broad expanse of sky, and is desired in wide diffusion throughout a large room, it is not easy to define the action of the different types of rib and prism. Stated broadly, the efficiency of the rib falls off more rapidly than that of

the prism as the sky angle decreases, and as the depth of the room increases.

Let us now look at the changes which we may bring about in some particular cases by the use of diffusing glass, instead of plane glass. Take first the ordinary Boston type of school room, 28 x 32 feet, with windows on two adjacent sides. We have two conditions to consider, the presence or absence of the sun at the window, causing a great difference in the amount and distribution of the light. Without the sun, we find ordinarily that the half of the room nearest the windows is fairly well lighted. The exception is the occasional city school, with its tall neighbors in close proximity to its too few windows. It is desirable when the sun is not shining upon the windows to strengthen the light in the rear half of the room. On the other hand, when the sun is shining through the windows, the half of the room farthest from the windows is fairly well lighted, and the chief source of complaint is the too great brightness near the windows. Resort is usually had to window shades of greater or less opaqueness to cut off the light as a whole, for the benefit of the pupils within a few feet of the windows. The result is that the back of the room is insufficiently lighted at all times.

Suppose, however, we should put a suitable ribbed or prismatic glass in the windows. It is hardly practical to so adjust the glass as to give to those near to and far from the windows exactly the same strength of light, but the ratio of intensities may readily be changed from 20 to 1, to 2 to 1.

Consider the case of a large mill room with large window areas. We are here much less concerned with the amount of the diffusion from any one window, since the number of windows is so great as to give a satisfactory diffusion in those parts of the room which are within 20 feet of the windows. The ribbed glass and prisms act in such a room as deflecting devices, to carry the excess of light near the windows bodily back into the middle of the room. I have in mind a mill with two wings of a similar exposure. One is glazed with plane glass, the other with diffusing glasses, and on any cloudy afternoon you may find the plane glass wing all gaslight, while the other is amply lighted with diffused daylight. It is hardly necessary to add that as I write, the further substitution of diffusing glasses is being carried out in this mill.

In the large city stores we have still another condition of affairs, for here we meet usually with a deep, narrow room, lighted only from one end, with a window the full width of the store. We may usually count on finding the lower half of the window obstructed by merchandise. The city store rarely has more than a limited sky angle. The one thing eminently suited to improve the light here is the prism, especially if it can be set in canopies over the sidewalk. The thousands of square feet of prisms which have been installed within the last four years in the stores of our large cities attest the real commercial value of this device for this work.

In offices and in small rooms we have still another set of conditions to meet. Except where the sky angle is very small, we need here essentially a diffusion of as wide an angle as possible, with a much less regard for the upward tipping of the beam. We find here that the glasses worked with a raised pattern are of especial value. Some of them are of pleasing appearance, and are known as "Florentine," "Maze," "Arabesque," and "Figured" glass. There are many others by several makers, but these are typical of the whole class.

Skylights have long been a source of trouble when the sun strikes full upon them, but the substitution of a diffusing glass scatters all about the room, and puts to good use the light which otherwise fell so strongly upon some one spot as to make imperative the use of some sort of an opaque shade.

It is to be regretted, but it is certainly true that strong objection is often made to the "shut in" feeling which some people experience in rooms glazed wholly with diffusing glass. Repeated legislative action has been urged to prohibit the use of this glass in factories, and as a result it is now customary to confine the use of diffusing glasses to the upper sash. A more serious objection comes from the unpleasant and often unbearable glare of the glass when in the bright sunlight. The prisms are especially bad in this respect, but a remedy may be found even with them, in the use of a thin white cloth shade, to be drawn only when the sun strikes the window. We thus have the light at its maximum in dull weather, and can yet temper its brightness when it is necessary to save the eyes of those working in direct line with the light.

The substitution of ribbed or figured sheet glass for plane gives rise to no new mechanical problems, but the setting of the prisms in small tiles has called for a great expenditure of time and money. It is not

quite certain that the present methods of holding the small tiles in metal frames by means of a cement filling or by an electrolytic deposit of copper are wholly satisfactory. The one is not easy to make tight while the other is so close a fit that the greatest care in relieving the frame from all strain is necessary, or the tiles become cracked or broken. The chief reason for making the prisms in small tiles has been heretofore the difficulty of rolling large sheets of prisms without deforming. The use of glass in large sheets for canopies over the sidewalks is prohibited by considerations of the safety of those passing underneath, so small tiles in stout metal frames must continue to be used for this work.

The action of prisms when set in canopies over a window is two-fold: first, as in the ordinary setting, to give an upward tip to the light; and second, to actually send through the window more light than would otherwise enter through it. Especially in narrow streets where the angle at which the light strikes the vertical is small, a canopy projecting into the street, even if of no greater area than the window will have incident upon it much more light. Being composed of total reflecting prisms, a canopy throws into a room almost all the light which falls upon it. Unlike the vertical prisms which are active by virtue of their refractive power, these total-reflection prisms have uppermost the surface through which the light enters, and they are more seriously affected by accumulations of dust and dirt.

The diffusion of direct radiant heat from the sun or from the sky follows much the same lines as in the case of light, but so large a proportion of the heat which enters a room comes in ways other than by direct radiation, that the main effect of the diffusing glasses is to prevent the local overheating of those portions of a room which are exposed to direct sunlight.

The criticism which has been offered several times, that the use of glass which prevents the direct entrance of beams of sunlight was injurious to the health of those living in rooms so glazed, is of course sheer nonsense. The action which light has upon disease germs can be operative as well through a diffusing glass as through plane glass.

In conclusion, we may safely predict a field of usefulness for the diffusing window, in improving the light in many rooms now dimly lighted, in making profitable the construction of rooms of greater depth, and in allowing of the closer approach to one another of tall buildings, with a resulting economy in land.

TRADE WITH EUROPE.

By WILLIAM H. LINCOLN.

Read January 14, 1901.

I HAVE been requested to speak to you this evening upon our export freight to Europe, or as I shall interpret it, our commerce with Europe. It will be my purpose, so far as I am able, to divest the subject of dry statistics and to explain the nature of this trade, the great developments that have taken place, and the rapid growth under favorable conditions. It is this trade that has given such wonderful prosperity to the country during the past three years, that put in motion all the wheels of industry, that has brought large earnings to our great railway lines, that has made money so abundant and created vast wealth for this country. It will be interesting and profitable to trace the source of these great benefits. It is a large subject, capable of almost indefinite expansion, of widest scope, and it will be possible only to deal with the most important branches of the trade. I am sure there is no more useful, interesting, or fascinating study than that which relates to the origin and growth of a trade with foreign peoples.

The character and extent of the commerce of a people determine in a great measure its influence in the world, and upon it depend its wealth and prosperity. The first steamship that crossed the Atlantic started from New York for Liverpool as far back as in 1819. This event was the forerunner of a new era in trade, revolutionizing former methods. And what progress has been made since that time! From wood to iron and steel, from sail to steam, from small craft to monsters of the deep, the ocean is now but a river, and the mighty steamships serve as a bridge to cross it. The terrors of the sea hardly have any existence, so swift, so certain have become the passages across it. The electric telegraph — the cable, have brought the remotest corners of the earth to our doors. Space and time are annihilated; merchandise is bought in this country; the freight engaged from point of shipment

in the West to its destination in Europe, and within a few hours sold in Europe at a price to yield a small commission — a fraction of a cent per bushel on grain. What facilities for human intercourse, for the transaction of the business of the world, and requiring improved methods, a firmer grasp of situations, a keener insight, more enterprise, more effort, and greater sagacity. The strife is more earnest, and competition closer. The country has been startled by the enormous growth of our export trade. The statistics have not been compiled for the entire year past, but I am able to give them for the eleven months of 1900. The total imports were $760,000,000, of which $139,000,000 were from the United Kingdom, and $93,000,000 from Germany.

The exports were $1,380,000,000, of which the United Kingdom received $535,000,000, and Germany $179,000,000, so that it will be seen that the United Kingdom purchased of us $400,000,000 in excess of our purchases from them, and this in eleven months. It is safe to say, as December is an active month, that the United Kingdom becomes our debtor to the extent of $500,000,000 per annum. As might be expected, our exports consist of food products and raw material. England is becoming more and more dependent upon other nations for her food supplies, and with this country now entering upon a period of close competition in the markets of the world in manufactured goods, it would seem that she has nearly reached the maximum of population she will be able to support. Just here it may be interesting to note that the United States produces

80 per cent. of the world's cotton.
80 per cent. of the world's corn.
25 per cent. of the world's wheat.
30 per cent. of the world's meat.
30 per cent. of the world's iron.
40 per cent. of the world's steel.
33 per cent. of the world's coal.

and more startling than all, her manufactured product is greater than England, France and Germany combined. Our export of manufactured goods amounted to $25,000,000 monthly in 1898, now increased to $40,000,000. In thirty years our manufactured output has increased from $3,700,000,000 to $13,500,000,000. These facts, indeed, fix our status to be the superior and favored nation of the world. Let us now examine somewhat in detail our trade with Europe, and these facts relate to eleven months of business.

GRAIN EXPORTS.

Corn, 152,000,000 bushels, value, $67,000,000.	To the United Kingdom, $32,000,000.
Wheat, 80 000 000 bushels, value, $58,000,000.	To the United Kingdom, $42,000,000.
Oats, 30,000,000 bushels, value, $9,000,000.	
Flour, 11,500,000 barrels, value, $43,000,000.	To the United Kingdom, $39,000,000.
Cotton, 6,000,000 bales, value, $260,000,000.	To the United Kingdom, $120,000,000. Germany, $68 000,000.

The supremacy of the United States as the greatest contributor to the world's meat supply, the fact that our exports greatly exceed that of any other country, that our animal product is second only in importance to cereal culture, render the study of this product of unusual interest. The intimate connection between livestock and corn must be borne in mind in order to understand the full import of the meat trade. It is estimated there are 40,000,000 swine slaughtered in the United States in a year, and in the raising of these there is a consumption of 800,000,000 bushels of corn, or one-third the entire crop.

As will be seen by the figures, England is the largest consumer of our meat products; in fact, nearly the whole of this business is confined to that country. The chief feature of the meat importation into Great Britain has been the change from the importation of salted to that of fresh meat. From 1871 to 1898, the quantity of salted meat declined over 25 per cent., while that of fresh meat increased almost 140 fold. Importation of hams into the United Kingdom has also been marked by a rapid displacement of Danish and German hams by the American product. In 1871 Holland and Germany furnished 33 per cent. of the total amount as compared with 57 per cent. from the United States. In 1891 the percentage was one-third of 1 per cent., and that of the United States 98 per cent. Since that time the trade has been monopolized by the United States and Canada. The United States furnished 94 per cent., and Canada 6 per cent. in 1898. In the exportation of mutton to Great Britain, we have taken no part. Of the total importation of 1898, 3,314,000 hundred weight, valued at $24,000,000, 57 per cent. was furnished by Australia, 33 per cent. by Argentina, and 8 per cent. by Holland. In this connection it may be interesting, especially as connected with the wool supply, to note that it is computed that there are 110,000,000 sheep in Australasia, 74,000,000 in Argentina, and 38,000,000 in the United States. The carcasses are frozen at point of shipment, and shipped by steamers especially fitted for the business.

FRESH MEAT.

The shipment of fresh meat furnishes a striking illustration of how a trade can be created and increased by the adoption of improved methods. The first shipment of fresh meat from this country was made in 1876 to Liverpool. The system of refrigeration adopted was crude as compared with that now in use. Ordinary ice boxes were constructed, and these were replenished with ice during the voyage. The meat frequently landed in a damaged and mouldy condition, especially in hot weather, causing large losses to shippers. The people were naturally prejudiced against American meat transported such a distance, and it required many years of persevering effort and greatly improved methods of transportation to overcome that prejudice. Many years passed before the ammonia process of cooling the refrigerators was perfected. There is now no complaint in regard to the condition of the meat on arrival. The shippers have established their own meat shops in the large centres of trade in the Kingdom, and the trade is now conducted at a saving in expense and with greater efficiency. There are now shipped on many of our large steamships 5,000 quarters of beef, the equivalent of 1,250 head of cattle. This trade has become of great importance to the steamship lines and to the country.

In recent years Australian beef has vigorously competed with the American product, and it now forms 20 per cent. of the whole product. The statistics for the eleven months of 1900 are as follows:

EXPORTS.

Bacon, 410,000,000 lbs., val., $32,000,000. United Kingdom, $27,000,000 Germany, $1,300,000.
Hams, 168,000,000 lbs., val., $18,000,000. United Kingdom, $17,000,000. Germany, $200,000.
Pork, 107,000,000 lbs., val., $7,000,000. United Kingdom, $5,000,000. Germany, $550,000.
Lard, 480,000,000 lbs., val., $32,000,000. United Kingdom, $12,000,000. Germany, 11,000,000.
Fresh beef, 300,000,000 lbs., val., $26,000,000, all to the United Kingdom.

Our total shipments of provisions amount to $170,000,000, and in 1889 they were $104,000,000. Fresh meat, 1890, $13,000,000; 1899, $23,000,000.

The shipment of fresh meat has caused a decline in canned beef and salt beef. The exports of canned beef have declined from $6,000,000 in 1890, to $2,500,000 in 1899; salt beef from $4,200,000 in 1890 to $1,080,000 in 1899. On the other hand, in salt pork there has been an increase from $4,700,000 in 1890, to $7,900,000 in 1899, and of pickled pork 18,800,000 pounds in 1890, to 91,700,000 in 1899.

To illustrate the increase in lard and hams exported to Europe:

Lard.	Hams.
1890. 384,000,000 pounds.	1890. $7,000,000.
1899. 626,000,000 pounds.	1899. 19,000,000.

In butter and cheese, nearly all of which is for Great Britain, there is a marked decline, especially in cheese: 1890, $7,300,000; 1899, $2,000,000.

No doubt this has been caused in part by improper or careless management of the business. The packages in which cheese is shipped are very frail, incapable of much handling, and as a consequence they are landed in bad condition, and the contents suffer damage. Then in the summer season these articles deteriorate, and unless shipped in refrigerators are delivered out of condition.

The imports into England of our provisions are rapidly increasing with increase of population, and also because the consumption *per capita* has increased 20 per cent. This is due to the lower price; fresh meat is now selling at one-half the price it was before our meat was imported.

LIVE ANIMALS.

There is no more interesting part of our foreign commerce than that relating to our live cattle trade. In 1875 I engaged for the steamer *San Marcos* the first shipment of live cattle from this country to Europe. That year 300 head were shipped, and we have been exporting for a good many years 300,000 head per annum, valued at $28,000,000, all to the United Kingdom. The increase is due to better facilities, improved fittings, etc.; the losses used to be heavy at times. In 1889 the Argentine Republic began to export in competition with us, so that in 1898 there were exported from the United States 369,000 head, or 65 per cent., and Argentina 89,000, or 16 per cent. Canada also exports live cattle.

It is interesting to note the changes that have taken place in the cattle producing countries of Europe. In 1871, which was before we exported any cattle, the total imports into Great Britain were 218,000 head. Holland was easily the first in supplying this trade, with 43 per cent., Germany second, with 31 per cent. of the whole. The traffic was thus essentially a Western European one, and the sea voyage was short. The relations of these countries remained approximately the same for some time until Denmark increased her shipments, and after 1876 that country became the chief European country of supply. The exports

from Denmark, however, rapidly declined after 1883, as did the whole European export to the United Kingdom, and entirely ceased in 1893. The chief feature of the live cattle trade has been the shifting of its incidence from Europe to America.

SHEEP.

The importation of live sheep into Great Britain is of declining importance. In 1878 892,000 head were imported, and in 1898 664,000, and value of sheep also has declined. The same process took place as in the case of cattle. The source of supply is now from United States, Canada, and Argentina — the latter had not made any shipments until 1890 — and at present ships 64 per cent. of the entire quantity, and the United States 22 per cent.

HORSES.

This trade is of comparatively recent origin, principally on account of the low prices of horses in this country. The exports the past eleven months have amounted to 27,000, valued at $4,000,000.

LEATHER.

I have taken quite an interest in the growth of this trade, because it has developed from very small beginnings. The first shipments were of sole leather, and now we export largely of finished leather. We exported last year 27,000,000 pounds of sole leather, valued at $5,000,000, of which England took 4,500,000, and finished leather having a value of $12,000,000, of which $9,000,000 went to England. We also shipped to Europe boots and shoes valued at $1,250,000.

ILLUMINATING OIL.

It will surprise you probably to hear that there were exported from this country to Europe 650,000,000 gallons of refined oil during the past year, valued at $40,000,000, and 112,000,000 gallons of crude oil, valued at $6,000,000.

MACHINERY.

Included in our exports to Europe is a large variety of manufactured goods, machinery, scientific apparatus, etc. Sewing machines, $2,500,000; typewriting machines, $2,000,000; telephone and electrical apparatus, $4,500,000, the amount having doubled in two years.

IRON AND COAL

A marvellous change has taken place in this country in respect to those two great sources of national wealth. The iron ore production in 1894 was 12,000,000 tons, and in 1899 it was 24,000,000 tons, as against 14,000,000 tons in Great Britain. Our product of coal was 230,000,000 tons, while Great Britain's was 220,000,000 tons. Our total exports to Europe of products of iron and steel were $120,000,000: Steel rails to Europe, 27,000 tons; hardware, $4,000,000; structural iron and steel, $3,500,000; wire, 160,000,000 pounds, $4,000,000. Agricultural instruments valued at $10,000,000 were exported to Europe. These figures show that the leadership has passed to the United States in the production of those raw materials upon which the manufacture of iron and steel depends. Nearly one-third of the world's output of iron ore has passed to the United States. Not only that, but the prices are lower in this country than in Europe. What interpretation is to be put upon these facts as outlined? It means industrial power at home and commercial prestige abroad. It means vast increase of national wealth. Hitherto agricultural products have been our main exports, and now we are to add the manufactured products. We are only at the beginning of our resources. The turning of this tide marks the end of the old and the beginning of a new era in our history. Hitherto, we have progressed slowly and gradually. That progress has been marked by revulsions in trade, — advance and decline — but during the past three years the nation has advanced by leaps and bounds, and we have become the great commercial nation of the world; not by accession of foreign territory, but by the development of our own resources. The enormous wealth that has been poured into this country has led to great industrial development. Companies with capital of hundreds of millions have been created, and the result is increased production at minimum cost.

I cannot close without referring to one branch of industry in which we have been sadly deficient — ship-building and our merchant marine.

There are dangers that will confront us. The history of other nations that have been great and powerful in their day reveals to us the effects of the intoxication of success, and the demoralizing influences of luxury and wealth. The two great counteracting forces that are at work in this country, and that will enable us as a people to overcome the temptations that beset us, and to pass through the ordeal in triumph and safety, are education and religion.

ON THE DRAINAGE, RECLAMATION AND SANITARY IMPROVEMENT OF CERTAIN MARSH LANDS IN THE IMMEDIATE VICINITY OF BOSTON,[1]

By WILLIAM LYMAN UNDERWOOD, Lecturer in the Massachusetts Institute of Technology, and Member of the Board of Health of Belmont.

It has long been recognized that the existence of "wet, rotten and spongy lands" in the near neighborhood of towns and cities may constitute a menace to the public health, and special attention has been drawn to such areas within the last three years, since it has been established with tolerable certainty that the mosquitoes for which they too often furnish a breeding place may become effective vehicles of malarial or intermittent fever. In almost every town in the state are to be found undrained areas of wet, sour and swampy lands which in many ways are a nuisance and more or less injurious to the public health. Pools of stagnant water are frequently found upon them, in which may be bred myriads of mosquitoes whose existence in any neighborhood is a damage quite apart from the fact that they may in all probability become the effective carriers of the germs of intermittent fever.

From such areas arise foul odors of decaying vegetation, and in the colder months of spring and fall the air, heavily laden with moisture, tends to impart to the surrounding neighborhood a cold and penetrating chill detrimental to the public health. Frequently these lands cover a very large tract whose ownership is divided among many individuals; very often the territory may cover lands lying in separate, though contiguous, towns.

The question arises, how can these conditions be remedied or the dangers from them be minimized? If it is possible to drain these spongy lands and so bring the soil back to a sweet and wholesome condition, who is to do the work, and at whose expense is it to be done? An individual owner generally cannot work to advantage unless he has the coöperation of his neighbors. How to bring about a unanimity of

[1] Read at the Quarterly Meeting of the Massachusetts Association of Boards of Health, Boston, January 24, 1901.

purpose and action on such a question is often a very difficult problem to solve, especially when it involves the possibly conflicting interests of two or more different towns. While it may in most instances be impossible to obtain concerted action through individuals, there is fortunately, if properly applied, a method by which much good may be effected, and that is through the local Board of Health — if the lands in question lie within one town — or by the united action of the Boards of Health of two or more towns whose interests are involved, provided it can be shown that the areas in question are detrimental to the public health. The laws which the State of Massachusetts has enacted to deal with such conditions are positive and plain, and briefly as follows:

Lands which are wet, rotten and spongy, and offensive to persons residing in their vicinity, or which are injurious to the public health, may be deemed a nuisance, and upon a hearing and petition, such nuisance may be abated. A Board of Health may also determine who shall bear the expense of making such improvements and the keeping of them in repair, whether it shall be the city, town, or persons, benefited thereby.

As a single illustration of what has already been accomplished along these lines in one case, and to show that still further steps seem absolutely necessary for the safety of the public health, a tract of territory will be considered, situated within five miles of the State House in Boston, lying in and between the cities of Cambridge and Somerville, and the towns of Arlington and Belmont, and known as the "Fresh Pond Marshes." It is the purpose of this paper to describe and illustrate the condition of these marshes as they now exist, and as they existed before certain sanitary improvements recently made by the Boards of Health of Belmont and of Cambridge had been carried out. In order to give a clear idea how these conditions were brought about, it will be desirable to state a few facts concerning the early history of the Fresh Pond Marshes.

In 1856 the Cambridge Water Company first began to use the waters of Fresh Pond for the city supply, and their charter also granted them the right to take the waters from Little and Spy Ponds and Wellington Brook. During that year F. W. Bardwell (a member of the Lawrence Scientific School) was employed to ascertain the amount of water available for the city's use. He made careful calculations and found that the average discharge from Fresh Pond and through Alewife Brook (see map) was a little over 2,000,000 gallons daily. From Spy

and Little Ponds and Wellington Brook, it was about 10,000,000 gallons daily. He reported that by building a dam across the culverts under the Lexington Branch Railroad the waters from these ponds and the brook could be forced back into Fresh Pond. It is not clearly shown just when Fresh Pond began to be supplied in this way, but it was probably sometime before it became necessary to do so. In a report of 1870, however, the following appears:

"A new gate and gatehouse have been built at the outlet of Fresh Pond, and flashboards have been erected on Alewife Brook where it passes under the Lexington Branch Railroad. These flashboards were rendered necessary, not only to secure the water flowing from Spy and Little Ponds, by conducting it into Fresh Pond, but also to enable the fish to escape from the pond to the ocean. There had been no water flowing from Fresh Pond for several months, while there was a constant flow from Spy and Little Ponds. By the dam at the railroad crossing, the tide is effectually shut out from all the ponds, and the water from Spy and Little Ponds is carried directly into Fresh Pond."

This system was evidently used until 1873, when two sewers were allowed to empty into Alewife Brook — one at Spruce Street, and another at Concord Avenue. In order to avoid contamination of the water supply of Cambridge by their sewage, the outlet of Alewife Brook was then permanently closed by filling in with dirt, and sheet piling was driven in across the brook at Concord Avenue. As a further safeguard, tide-gates were built at Broadway in Somerville, to prevent the tide-water from backing the sewage upon the meadows. As Cambridge, however, could not afford to lose the amount of water which she had been getting from Little and Spy Ponds and Wellington Brook, she built in 1875 a conduit to carry this supply directly from those ponds and Wellington Brook into Fresh Pond. (This is shown upon the map.) For a number of years this system appeared to be satisfactory; but with the rapid increase in the population of Cambridge, it soon became evident that a larger water supply was necessary. It also became clear that the conduit water was being badly polluted, for Wellington Brook, with its drainage area of 2,500 acres (the greater part in a state of high cultivation and heavily manured), was becoming a serious danger. In 1879 the Cambridge Water Board had borings made all over the territory between the meadows and Fresh Pond. As a result they found a rapid undercurrent of water setting from the marshes to the pond, and in their report for that year they stated that it was very important

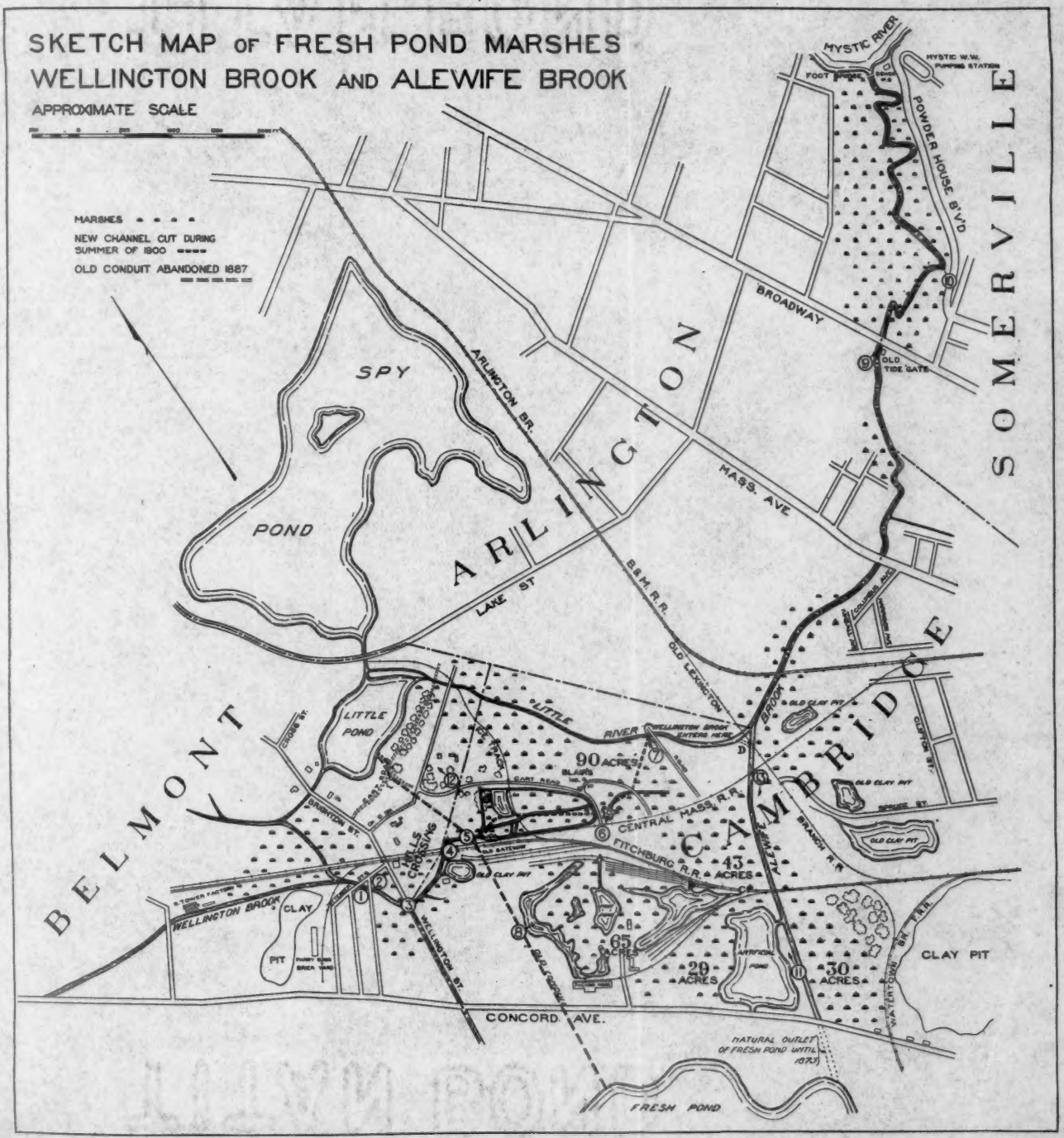
SKETCH MAP of FRESH POND MARSHES
WELLINGTON BROOK AND ALEWIFE BROOK
APPROXIMATE SCALE
MARSHES
NEW CHANNEL CUT DURING SUMMER OF 1900
OLD CONDUIT ABANDONED 1887
MYSTIC RIVER
MYSTIC W.W. PUMPING STATION
POWDER HOUSE B'V'D
SOMERVILLE
BROADWAY
OLD TIDE GATE
SPY POND
ARLINGTON BR.
MASS. AVE
ARLINGTON
LAKE ST
B&M R.R.
OLD LEXINGTON
LITTLE POND
LITTLE RIVER
WELLINGTON BROOK ENTERS HERE
BELMONT
CRESCENT ST.
BRIGHTON ST.
CROSS ST.
CELLS CROSSING
90 ACRES
CENTRAL MASS. R.R.
FITCHBURG R.R.
CAMBRIDGE
ALEWIFE BROOK
BRANCH R.R.
OLD CLAY PIT
43 ACRES
WELLINGTON BROOK
CLAY PIT
WELLINGTON ST.
65 ACRES
29 ACRES
30 ACRES
CLAY PIT
CONCORD AVE.
NATURAL OUTLET OF FRESH POND UNTIL 1873
FRESH POND

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FIG. 1. — A 10-inch pipe located in Belmont, 700 feet from the Cambridge line. Through this pipe was flowing, on July 27, 1900, all the water from Wellington Brook at that time. The bridge, on Hittinger Street, was being repaired and the water was temporarily cared for in this way. It will be seen that a much smaller pipe would have answered the purpose. (Compare this with Figure 4 taken on the same day.)

FIG. 2. — Looking southeast, from bridge on Hittinger Street, July 27, 1900; showing pool in Belmont into which the water from the 10-inch pipe shown in Figure 1 was flowing. This pool was 3 feet deep, and well indicates the lack of proper drainage.

FIG. 2*a*. — The same place shown in Figure 2, Nov. 22, 1900, and after heavy rains. It will be seen how the water has been lowered in spite of the rains and drawn off by simply clearing out the channel in Cambridge territory. On the right bank will be noticed the roots of the rushes which are to be seen in Figure 2 growing luxuriantly.

FIG. 3. — July 27, 1900, looking east from Wellington Street. The channel of Wellington Brook is filled with rushes. Within half a mile, in Belmont, is a schoolhouse from which there are more absences relatively from sickness than from any other school in that town.

FIG. 3*a*. — November 22, 1900, the same view as in Figure 3, but after the new channel had been made.

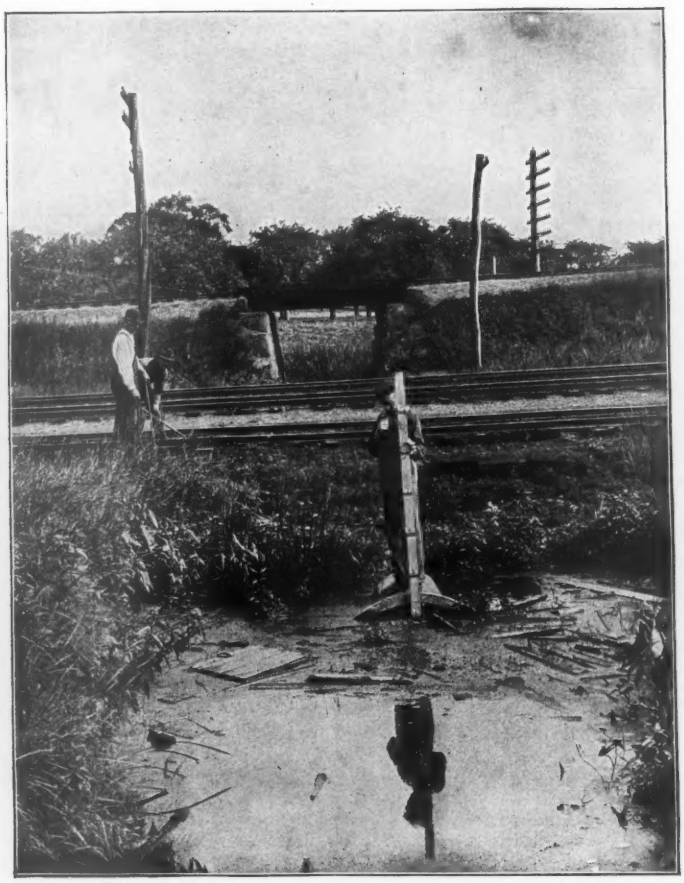

FIG. 4. — July 27, 1900; a 4-foot pipe and culvert under the Fitchburg Railroad and Central Massachusetts tracks, 1,200 feet below the 10-inch pipe shown in Figure 1. This pipe was standing almost full of water; while the 10-inch pipe further up the stream was not half filled, though carrying all the flow of Wellington Brook. At the lower end of the culvert rushes were growing and filling the channel. These and other obstructions further down the stream were holding the water back and keeping the pipe full.

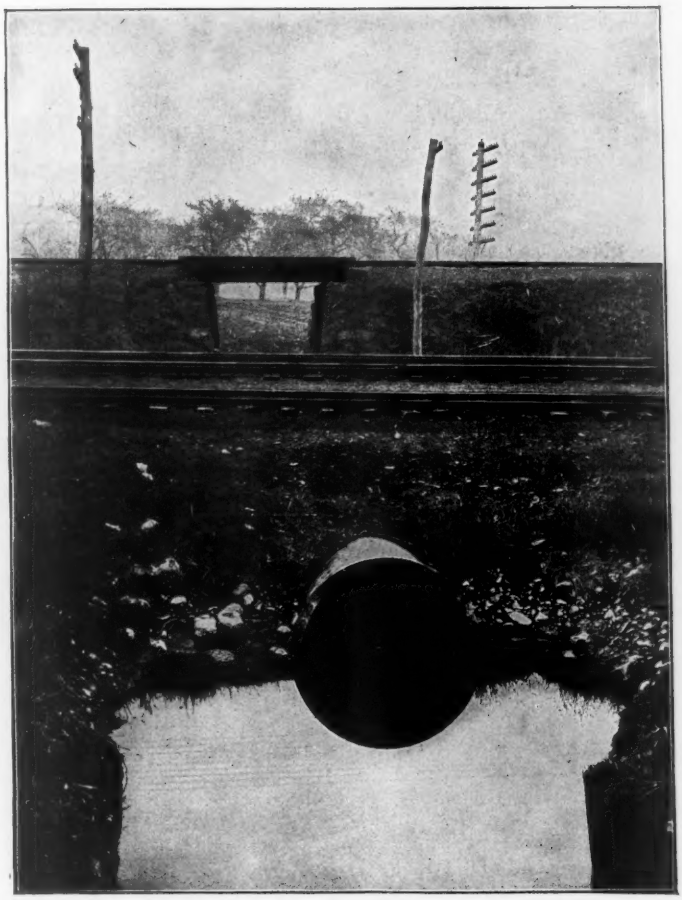

FIG. *4a.* — November 22, 1900, from the same point as Figure 4, but after the channel had been cleaned out. It will be seen that the pipe is but half full of water, though the view was taken after a heavy rainfall. When the brook was first cleared out, there were only five inches of water flowing through the culvert.

FIG 5. — July 27, 1900. An obstruction of willow trees growing directly in the bed of Wellington brook. The surface of the water is covered with a thick scum of duckweed, with the exception of the dark space in the centre, into which, just before the picture was taken, a stone had been thrown.

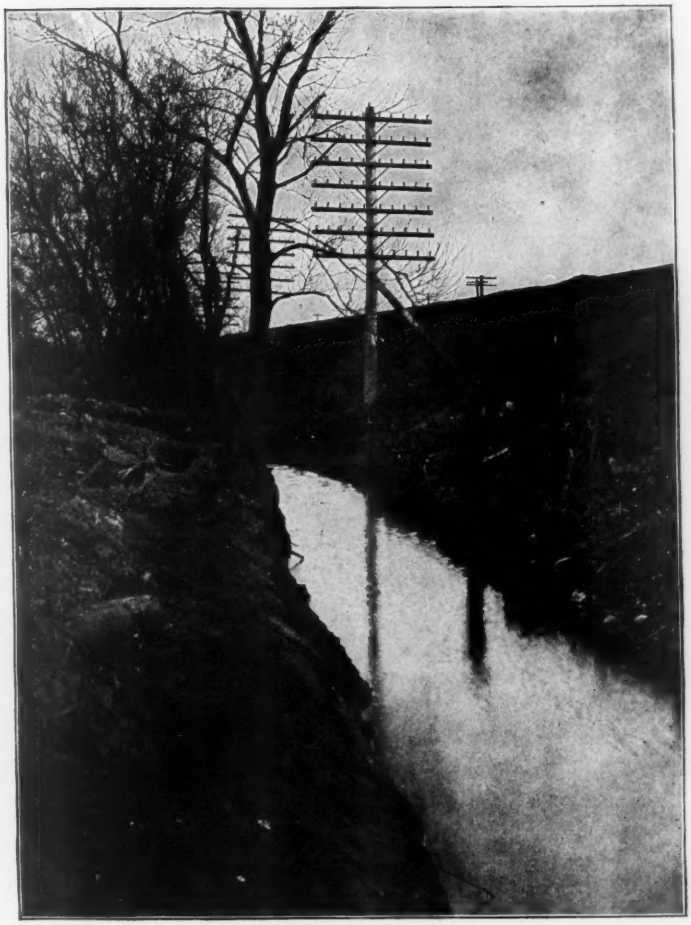

FIG. 5*a*. — November 22, 1900. From the same point as Figure 5, but showing the new channel. Just beyond the willow tree and to the left, was situated formerly the gateway that carried the water through the conduit into Fresh Pond. (See map.)

FIG. 6. — July 27, 1900. A stagnant pool, the surface of which was covered with green scum. After the new channel was constructed this pool was lowered about 2 feet. In the winter of 1899–1900, on a number of occasions, the water in this vicinity rose so high that it covered the roads and prevented children living at Blair's house (see map) from attending school.

FIG. 7. — July 27, 1900. The mouth of Wellington Brook where it enters Little River. From this point to Wellington Street the new channel was constructed. It will be seen, by referring to the map, that here the stream had become completely obstructed. For some distance the water of the Brook had to soak its way through the soil to Little River.

FIG. 8. — December 8, 1900; looking east, and showing conditions still existing at the worst spot on the marshes. In this section there are 65 acres, bounded on the north by the tracks of the Fitchburg Railroad; on the east by the tracks to the factory of the Boston Packing and Provision Co.; on the south by Concord Avenue; and on the west by high land, — from which this view was taken. Most of this territory is under water throughout the entire year. Formerly, the greater part of it was covered with a growth of maple trees; but these have all been killed by the gradually-rising water. At points *A* (see map, directly under 6) and *B* (more to the right) culverts used to drain this section into Wellington Brook; but now these waterways have been filled in and the only outlet is at *C* (see map, point on railroad tracks north of Artificial Pond). From the north side of the Fitchburg Railroad tracks, at this point, the water has to find its way across the marshes as best it can, for there is no channel for it.

FIG. 9. — The old tide-gate house, at Broadway, in Somerville; built in 1872 and abandoned in 1896.

FIG. 10. — Looking north from Powder House Boulevard, and showing marshes between Broadway and the Mystic River. If tide-gates were constructed at the point where the foot-bridge crosses Alewife Brook (see map) near its junction with the Mystic River, this marsh land could be changed into a lagoon, in which the brook waters could be stored during the period of high tide in the river. By this means it is probable that the water-table of the Fresh Pond marshes could be lowered 3 feet.

FIG. 11. — The shore of Artificial Pond. (See map.)

FIG. 12. — A view near the marshes, showing the agricultural possibilities of this locality.

FIG. 13. — The unreclaimed portion of the marshes as it exists to-day. Looking southeast from the Massachusetts Central tracks, December, 1900. Within half a mile of this swampy area there are located 1,161 dwelling houses; 128 of these are in Belmont, 201 in Arlington, 307 in Somerville, and 525 in Cambridge.

FIG. 14. — Looking east along the south bank of Wellington Brook, in Belmont, about a quarter of a mile above the point where it passes under Concord Avenue. The brook is hidden by the shrubbery to the left. In the lower right-hand corner is seen a portion of a lily pond, and in the background is a meadow kept sweet, dry and fertile by means of proper drainage.

FIG. 15. — The lily pond, a part of which is shown in Figure 14. Here are grown aquatic plants, including six hardy varieties of water lilies that bloom from May to October and require no special care. In the water are hundreds of gold-fish that feed upon the larvæ of mosquitoes and serve to keep this insect pest in check. In such ponds these fish thrive and multiply, surviving even the coldest winters of the locality.

Figures 14 and 15 illustrate what might be accomplished on the Fresh Pond marshes by proper drainage and care.

that these meadows should be kept clean in order to avoid contamination of the public water supply. The marshes are to-day in a worse condition than they were then, and if the opinion of the Water Board was correct, must still menace the purity of the waters of Fresh Pond. To avoid further contamination and to meet the growing demand, Cambridge in 1887 began to take its main supply from Stony Brook in Waltham, and Little and Spy Ponds and Wellington Brook were abandoned as sources of water supply.

The condition of the meadows at this time from a sanitary point of view, was far from satisfactory. Naturally, the channel of Wellington Brook, through disuse, had become considerably obstructed below the point where its water was diverted by the conduit. Rank weeds and other growing vegetation in some places completely filled the bed of the stream. For a number of years the farmers had entirely neglected the land in this vicinity. Prior to 1880, and as long as the ice business of Fresh Pond was in a flourishing condition, these marshes were cared for, the channels of the brooks were annually cleaned out and the whole meadows thoroughly ditched. Heavy crops of meadow hay were harvested from them and found a ready market with the ice men, who used large quantities for packing in their ice houses. The Fresh Pond Ice Company alone bought 100 tons of hay a year, frequently paying as high as $20 a ton for it. In 1888 the last ice house was removed from the pond, and from that time until the present (a period of some twelve years) no attention has been paid by the owners to the drainage of this large territory. Year by year the water has been rising higher and higher upon the fields until stagnant pools have come to exist all summer long, and offensive odors of decaying vegetation are given off, where twenty years ago crops of good meadow hay were cut annually. Malaria has crept in, and the whole district has threatened the health of the surrounding towns. It was this condition of affairs that the Board of Health of Belmont was called upon to investigate.

It was at once apparent that the town by itself could take no effective steps to alleviate the trouble, as the backing up of the waters of Wellington Brook upon Belmont lands was due to obstructions further down stream within the limits of Cambridge. Coöperation with the Board of Health of that city seemed to be the only remedy, and early in the fall of 1900, through the united action of the Boards of Health of Cambridge and Belmont, a considerable area of worthless and un-

wholesome territory in the vicinity of Hill's Crossing was readily and successfully reclaimed.

For this purpose a broad new channel, 10 feet wide and 4 feet deep, was constructed from the point where Wellington Brook enters Little River to the Belmont line, a distance of half a mile. This has so thoroughly drained the immediate district that the water level has in some places sunk more than 40 inches. Farther up the stream in Belmont, lands which were under water last summer — one of the dryest seasons in many years — have been so thoroughly reclaimed that they are now dry and available for cultivation. The map and photographs will serve to show the extent and character of this work better than any merely verbal description could possibly do, and to them the reader is referred for detailed information.

The work which has already been done through the combined action of the Boards of Health of Cambridge and Belmont, has cost about $1,600, of which Cambridge's share was $1,100, and Belmont's, $500. No assessment upon any of the landholders has been made by either of the Boards, as it was held that these unsanitary conditions were brought about through natural causes, and that their removal was for the common good of the public at large.

While Belmont has no further cause of complaint in so far as her own lands are directly concerned, that town is nevertheless near enough to a portion of territory which still remains undrained to feel its evil effects. It is to be hoped that some method will soon be devised whereby the towns and cities chiefly concerned (Belmont, Arlington, Cambridge and Somerville) may coöperate and adopt some definite measures concerning the sanitary treatment of these lower marshes for their mutual benefit, and also for the benefit of the public at large, as the condition of these may materially affect the health of other near-by towns.

There is still much to be done before some of the neighboring territory can be brought into a healthful and useful state. To accomplish this the coöperation of Arlington, Somerville and Cambridge with Belmont is indispensable. The placing of tide-gates at the mouth of Alewife Brook where it empties into Mystic River would remedy existing evils at comparatively small expense. This whole neighborhood possesses many natural beauties, and if developed, could be made wholesome and attractive, instead of what it now is, an unsightly area of waste and swampy lands, and a menace to the public health.

A map of the Fresh Pond marshes and some of the contiguous territory has been prepared under the author's direction and is shown above. The boundaries of the cities and towns immediately concerned are clearly indicated, as are also the course of Wellington Brook, Alewife Brook, and the location of the Mystic River, as well as of the new channel which has already proved so effective.

Photographs made by the author illustrating what has been done, as well as the need of still further improvements in the lower part of the territory under consideration, are appended. The legend under each will suffice for its explanation. The points where the photographs, Figures 1, 2, 3, etc., were taken, are indicated on the map by corresponding numerals enclosed in circles, and in several cases small arrows adjoining the circles show the direction in which the camera was pointed.

NOTE ON DRAINAGE AND MOSQUITOES.

"After all, the best of the means which may be adopted against mosquitoes will always consist in the abolition of their breeding places. Small pools with stagnant water can be 'treated,' but it is a great deal better to drain them or to fill them up. Swamp areas must sooner or later be drained. It is perfectly obvious that the sooner this is done the better from every point of view, not only from that of human health, but from the increased value of real estate in the neighborhood, and from the practical value of the reclaimed land itself. The time is coming, and rapidly, when this drainage of large swamps will not remain a matter which concerns the individual owner of the land, but one for town or county action, and even for States. The report of T. J. Gardner on the policy of the State respecting drainage of large swamps, published in the Report of the Board of Health for New York, Albany, 1885, although antedating the recent important mosquito discoveries, is well worth reading by all public-minded persons, and the annual reports of the State Geologist of New Jersey, for 1897 and 1898, in which the reclamation of the great Hackensack Meadows, near Jersey City, Newark, and Elizabeth, New Jersey, make interesting reading along this line. Work on these marshes has actually been begun. The solution of this case is taking the form of separate action by cities and their municipalities, each improving the territory within its corporate limits. The city of Newark has a tract of 4,600 acres of marsh within its limits. Jersey City has within its limits 2,086 acres of tide-marsh,

and Elizabeth has 2,658 acres. The three cities, therefore, have about 8,700 acres of the 27,000 acres lying between Elizabeth and Hackensack. The sanitary importance of reclaiming these lands is of the greatest, but the capabilities of the improvement plans are also attracting attention on the part of capitalists and business men, who see in these tide-lands valuable sites for manufacturing, industrial, and commercial activity." — *Professor L. O. Howard, Entomologist, United States Department of Agriculture.* "Notes on the Mosquitoes of the United States," p. 63. Washington, 1900.